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Perception of Phrasal Prosody in the Acquisition of European Portuguese

Cátia Sofia Severino

Orientador(es): Prof. Doutor Sónia Frota
Prof. Doutor Marina Vigário
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Tese especialmente elaborada para obtenção do grau de Doutor no ramo de Linguística, na especialidade de Linguística Portuguesa

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" É semelhante a um grão de mostarda, que um homem tomou e plantou no seu campo; o qual grão é, na verdade, a menor de todas as sementes, mas depois de crescido, é a maior das hortaliças e faz-se árvore, de tal modo que as aves do céu vêm pousar nos seus ramos."

Mateus 13, 31-32

"Se tivésseis fé como um grão de mostarda, diríeis a esta amoreira: 'Arranca-te daí e vai plantar-te no mar', e ela obedecer-vos-ia.

Lucas 17, 5-10

Abstract

A central issue in language acquisition is the segmentation of speech into linguistic units and structures. This thesis examines the role played by phrasal prosody in speech segmentation in the acquisition of European Portuguese, both in the processing of globally ambiguous sentences by 4 and 5 year old children and in early word segmentation by 12 month-old infants.

Past studies have shown that phrasal prosody is used by adults in ambiguity resolution, for example to disambiguate syntactically ambiguous sentences involving a low or high attachment interpretation of a given phrase (e.g, Hide the rabbit with a cloth). In a first exploratory experiment, and given previous unclear findings in the literature on European Portuguese, we investigated whether prosodic phrasing might guide speech chunking and interpretation of these globally ambiguous sentences by adult listeners. In an eye-tracking experiment, which also included a pointing task, we found that EP adult speakers were not able to use phrasal prosody to disambiguate the structures tested. Both the results from eye gaze and the pointing task indicated the presence of a high attachment preference in the language, regardless of phrasal prosody. These findings required a better understanding of adult interpretation of these utterances before a productive study could be conducted with young children. Building on the lessons learned from this exploratory study, we conducted two new experiments examining young children (and adults) abilities to use prosody, in a different sort of globally ambiguous utterances where differences in phrasal prosody were triggered by the syntax-prosody interface and part of the common, default prosody of the sentences (i.e., in compound word versus list reading structures, like 'guarda-chuva e pato,' *umbrella and duck vs.* 'guarda, chuva e pato', *guard, rain and duck*). An eye-tracking paradigm (along the lines of De Carvalho, Dautriche, & Christophe, 2016a) was used to monitor the use of phrasal prosody, namely the contrast between a Prosodic Word boundary (PW) in the compound word interpretation and an Intonational Phrase boundary (IP) in the list interpretation, during auditory sentence processing. An off-line pointing task was also included. Results have shown a clear developmental trend in the use of phrasal prosody to guide sentence interpretation, from a general inability at age 4 to a still developing ability at age 5, when local prosodic cues were still not enough and the support of distal cues was necessary to achieve disambiguation, unlike for adults.

While the previous experiments investigated the ability to use prosody to constrain lexical and syntactic analysis, thus looking into the combination of lexical, syntactic and prosodic knowledge at a young age, in a final set of experiments, we asked whether phrasal prosody is exploited to chunk the speech signal into words by infants, in the absence of prior lexical knowledge. Using a modified version of the visual habituation paradigm (Altvater-Mackensen & Mani, 2013), we tested 12-month-olds use of phrasal prosody in early word segmentation beyond the utterance edge factor, by examining the effects of two prosodic boundaries in utterance internal position, namely the IP boundary (in the absence of pause) and the PW boundary. Our findings showed that early segmentation abilities are constrained by phrasal prosody, since they crucially depended on the location of the target word in the prosodic structure of the utterance.

Implications of the findings in this thesis were discussed in the context of prosodic differences across languages, taking advantage of the atypical combination of prosodic properties that characterizes EP.

Keywords: Phrasal prosody; perception; disambiguation; speech segmentation; language acquisition and development.

Resumo da Dissertação

No âmbito da aquisição da linguagem, a segmentação de fala em unidades e estruturas linguísticas é uma questão central. Esta dissertação examina o papel desempenhado pelo fraseamento prosódico na segmentação de fala, na aquisição do Português Europeu (PE), no que diz respeito ao processamento de frases globalmente ambíguas por parte de crianças aos 4 e 5 anos de idade e à segmentação precoce de palavras aos 12 meses.

Estudos anteriores mostraram que o fraseamento prosódico é usado pelos adultos na resolução de ambiguidade, por exemplo, para desambiguar frases sintaticamente ambíguas envolvendo uma interpretação de *low* ou *high attachment* de um dado sintagma (e.g.,'Hide the rabbit with a cloth' *Esconde o coelho com um pano*). Num estudo exploratório, e dados os resultados pouco claros de trabalhos anteriores para o Português Europeu, investigámos se o fraseamento prosódico poderia guiar a organização da fala em unidades específicas, bem como a interpretação das frases globalmente ambíguas, por parte de participantes adultos. Numa experiência de eye-tracking, que incluía também uma tarefa de apontar, observámos que os participantes adultos do PE não conseguiram usar o fraseamento prosódico para desambiguar as estruturas testadas. Quer os resultados do movimento dos olhos quer os da tarefa de apontar evidenciaram a preferência pelo *high attachment* na língua, independentemente do fraseamento prosódico envolvido. Estes resultados implicaram compreender melhor a interpretação adulta destes enunciados antes de se conduzir um estudo com crianças. Com base nas observações feitas neste estudo exploratório, conduzimos duas experiências novas por forma a examinar a capacidade de uso da prosódia, por parte das crianças (e adultos), num outro conjunto de enunciados globalmente ambíguos, em que as diferenças de fraseamento prosódico foram desencadeadas pela interface sintaxe-prosódia e por parte da prosódia *default* das frases (i.e., em compostos *versus* estruturas em formato de lista, como 'guarda-chuva e pato,' *vs.* 'guarda, chuva e pato'). Um paradigma de eye-tracking (na linha de De Carvalho, Dautriche, & Christophe, 2016a) foi usado para monitorizar o uso do fraseamento prosódico, nomeadamente o contraste entre uma fronteira de Palavra Prosódica (PW) na interpretação de composto e uma fronteira de Sintagma Entoacional (IP) na interpretação de lista, durante o processamento auditivo da frase. Também foi incluída uma tarefa off-line de apontar. Os resultados mostraram um claro desenvolvimento no uso do fraseamento prosódico na interpretação das frases; de uma incapacidade geral de interpretação das frases aos 4 anos a uma clara evolução nas competências aos 5 anos, altura em que as pistas prosódicas locais ainda são insuficientes e o apoio do contexto prosódico da frase é necessário para alcançar a desambiguação, diferentemente do adulto.

Enquanto as experiências anteriores investigaram a capacidade de usar a prosódia para restringir a análise lexical e sintática, olhando para a combinação de conhecimento lexical, sintático e prosódico numa idade precoce, num conjunto final de experiências, questionámos se o fraseamento prosódico é explorado, por parte das crianças, para organizar o sinal de fala em palavras, na ausência de conhecimento lexical prévio. Recorrendo a uma versão modificada do paradigma *visual habituation* (Altvater-Mackensen & Mani, 2013), testámos o uso do fraseamento prosódico para a segmentação precoce de palavras além do fator limite do enunciado, por parte de crianças com 12 meses de idade. Examinámos o efeito de duas fronteiras prosódicas em posição interna de enunciado, nomeadamente a fronteira de IP (na ausência de pausa) e a fronteira de PW. Os nossos resultados mostraram que a capacidade de segmentação precoce é afetada pelo fraseamento prosódico, na medida em que depende da localização da palavra-alvo na estrutura prosódica do enunciado.

Partindo da combinação atípica das propriedades prosódicas que caracterizam o PE, as implicações do conjunto de estudos desenvolvidos no âmbito desta dissertação foram discutidas no contexto das diferenças prosódicas entre línguas.

Palavras-chave: Fraseamento prosódico, percepção, desambiguação, segmentação de fala, aquisição e desenvolvimento da linguagem.

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List of Abbreviations

EP	European Portuguese
ERP	Event-Related Potentials
ET	Eye Tracking
HPP	Headturn Preference Procedure
IP	Intonational Phrase
NP	Noun Phrase
PhP	Phonological Phrase
PP	Prepositional Phrases
PW	Prosodic Word
SEP	Standard European Portuguese

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1 Introduction

This work investigates the role of phrasal prosody in speech segmentation in language acquisition. By conducting a series of experiments with children acquiring European Portuguese (and with adults), we aimed to contribute to the understanding of the role of prosody, and more specifically the role of prosodic phrasing, in the segmentation of speech into smaller units and structures.

Although several studies in the past have shown that prosody provides cues to word and phrase boundaries in general, a number of aspects remain little explored, namely prosodic constituency which includes boundaries of different levels, and the ways prosodic boundaries are implemented in different languages. Looking at the range of prosodic boundaries, research has typically either focused on higher prosodic units, such as the Phonological Phrase (PhP) or the Intonational Phrase (IP), or looked at word level speech cues other than Prosodic Word boundaries (PW), such as stress. There is a generalized agreement as to the role played by the IP boundary in speech segmentation across languages, largely explained by the strong cues usually found at IP breaks, such as final lengthening, pitch modulation and pause. In languages like French, furthermore, PhP boundaries have also been argued to provide relevant information for lexical and syntactic analysis of the speech signal (Christophe, Peperkamp, Pallier, Block, & Mehler, 2004, in adults; Gout, Christophe, & Morgan, 2004, in infants). At the word-level, there is extensive literature showing that stress may play a major role in speech segmentation in various languages (Vroomen, Tuomainen, & de Gelder, 1998; Houston, Jusczyk, Kuijpers, Coolen, & Cutler, 2000; Thiessen & Saffran, 2007; and others). Other aspects of word prosody, however, have attracted much less attention.

Our investigation is focused on the role of phrasal prosody at different levels of prosodic organization, in infants and in young children. Where relevant, we have also tested adults. In the case of how prosody is used in ambiguity resolution, the results of the experiments with adults are instrumental for the experiments to be conducted with young children, since they allow us to determine the features of the system the child is acquiring.

In chapter 2, we describe the background of the present research, reviewing relevant studies for different languages, and also for European Portuguese (EP). EP is a language with particular interest for cross-linguistic comparison since it presents a combination of prosodic properties that sets it apart from both Romance and Germanic languages, two well studied groups of languages. Like in many other languages, in EP the IP is strongly cued by prosodic means. It is well established, however, that the same is not true of the PhP, which, although a functional domain in EP phonology, is often not prosodically marked (Frota 2000, 2014). In addition, although word size and stress distribution in EP are such that a much more variable pattern exists in the position of stress relative to word boundaries than in English, EP has a rich prosodic word phonology, with stronger cues for the PW than in most other Romance languages (Vigário, 2003; properties description at chapter 2). Investigating how phrasal prosody impacts speech segmentation in the acquisition of EP may therefore provide a relevant contribution to the understanding of language general and language specific mechanisms and developmental trends in speech segmentation.

The first of our experiments was an exploratory study on ambiguity resolution at phrasal level by adult speakers (chapter 3). The results provided an indication of the role of PhP and IP phrasing in adult speech processing by adults, indicating that phrasal prosody was not used to disambiguate the structures tested. In chapter 4, we investigated speech segmentation by 4 and 5 year old children, through an experiment on ambiguity resolution based on prosodic boundary properties, using a different type of globally ambiguous sentences from that used in chapter 3. The same experiment was conducted with adults as well. In chapter 5, we looked at early word segmentation by 12 month old infants, conducting two experiments where target words are either aligned with the prosodic boundaries of IPs or simple PW boundaries. In both conditions, word segmentation in utterance internal position (and not at utterance edge) was investigated. Finally, in chapter 6, we conclude with a summary and discussion of our findings, highlight the major contributions of this work and indicate directions for future research.

2 Background

In order to extract and process linguistic information in the speech stream, speakers have to be able to access and identify the words and phrases in it. This means that they must acquire proficiency in segmenting by recognizing the linguistic units and structures, and, upon this, extract the information conveyed.

The question of which linguistic information is relevant to segment the continuous speech and what is the precise role of that information in language acquisition and processing has been a fundamental issue in language studies. One approach to this matter consists of looking at the various cues that could take part in the process. Segmental and suprasegmental cues, like phonotactic cues, distributional regularities or stress distribution constitute the focus of investigation in most of the work (see Davis, Marslen-Wilson, & Gaskell, 2002; Gervain & Mehler, 2010; for review). Adult data allowed identifying some of the features that were relevant both in perception (Cutler & Norris, 1988; Saffran, Newport, & Aslin, 1996) and in production (Cairns, Shillcock, Chater, & Levy, 1997), contributing to cognitive modeling (McClelland & Elman, 1986; Gaskell, M. G. & Marslen-Wilson, 1997; Christiansen, Allen, & Seidenberg, 1998). These studies revealed the importance of prosody in language processing by children and adults, showing that language prosodic properties constrain speech segmentation and allow ambiguity resolution (Mersad, Goyet, & Nazzi, 2010; Millotte, René, Wales, & Christophe, 2008; Snedeker & Yuan, 2008).

Many studies have demonstrated that cues to prosodic boundaries are used in speech segmentation and language processing in several languages, like English, French, Korean and German. Adults have been shown to use these cues at the prosodic word level (Cho, McQueen, & Cox, 2007; Dilley & McAuley, 2008), and at the phrasal level (Wightman, Shattuck ‐ Hufnagel, Ostendorf, & Price, 1992; Millotte, René, Wales, & Christophe, 2008). In particular, intonational phrase boundaries have been found to be especially robust and consistently used across languages (Price et al., 1991; Ischebeck et al, 2008; among others). However, for the other levels of prosodic structure, namely the word and the phonological phrase levels, results have been less consistent across languages and studies (Millotte, René, Wales, & Christophe, 2008; Li & Yang, 2009). For European Portuguese, perception studies have shown that prosodic boundaries are relevant to resolve temporary ambiguity, but with differences between boundary levels and type of experimental task (Frota et al., 2010; Severino, 2011).

It is known that several linguistic features are perceived from birth and in the very first months of life. There is a very early sensitivity to language discrimination based on suprasegmental information, such as rhythm (Moon, Cooper, & Fifer, 1993; Nazzi, Bertoncini & Mehler, 1998), acoustic correlates of prosodic boundaries (Christophe & Mehler, 2001), intonation contours (Mampe, Friederici, Christophe, & Wermke, 2009; Frota, Butler, Lu, & Vigário, 2016), and also sensitivity to segmental information (McMurray & Aslin, 2005). Once it is established that infants are able to perceive all these features, the question arises as to whether all of them or only a subset, if any, play a role in speech segmentation and when do the relevant features start being used for that purpose.

In order to answer these questions, new research methods were developed. First, studies explored production data to determine which features were present in infants' speech (Echols & Newport, 1992). Second, research in perception added more information to a wider picture. The introduction of the Headturn Preference Procedure became a landmark in studies of infant speech perception (Kuhl, 1985; Werker, Polka, & Pegg, 1997, for method review). Studies that followed Kuhl (1985) tested infants mainly with single features, such as phonetic discrimination, rhythm, pitch and syllabic strings segmentation. For example, Morgan (1994) tested 8-month-old's segmentation abilities with manipulated syllabic strings not longer than 3 syllables, based on rhythmic patterns, and showed their ability to recognize relevant linguistic units in a sound string. Jusczyk & Aslin (1995) adapted the Headturn Preference Procedure (HPP) to test infants' segmentation capacities using longer and non-manipulated sentences (Jusczyk et al., 1999). Many other studies adapted Jusczyk & Aslin's procedure, searching for the exact cues used by infants in word segmentation (Seidl & Johnson, 2006; Bosch et al., 2013; Johnson, Seidl, & Tyler, 2014; Floccia et al., 2016; among others). Other methods enlarged the scope of procedures used in the study of speech segmentation, such as modified versions of the visual habituation paradigm (Altvater-Mackensen & Mani, 2013). Still other methods allowed more fine-grained information about infants' processing to be gathered, with less dependence on experimenter's data coding, thanks to its automation. Among the most used are eye tracking (ET) and event-related potentials (ERP). The experiments reported in this work used ET and a modified version of the visual habituation paradigm.

The development of these methods brought to light new findings. Jusczyk & Aslin (1995) showed that differences in listening time between two age groups showed that 7,5 month olds, but not 6 month olds, were able to recognize target monosyllabic words beginning with a consonant in fluent utterance production. Investigations into speech segmentation have also explored infants' early sensitivity to the rhythmic properties of languages. Studies revealed a starting preference based on the native stress pattern (trochaic or iambic). For example, English infants were able to successfully segment disyllabic words at 7,5 months based on the general trochaic pattern, but miss-segmented when presented with a less frequent stress pattern. They were only able to segment words with the less frequent stress pattern, at 10,5 month, indicating a trend in development (Jusczyk, Houston, & Newsome, 1999).

Investigations into the role of distributional regularities of phonemes and syllables have shown these regularities are exploited in word segmentation and word learning both by adults and toddlers (Graf-Estes, Evans, Alibali, & Saffran, 2007; Mirman, Magnuson, Estes, & Dixon, 2008). However, these studies, similarly to most word segmentation studies, did not consider the prosodic structure of the language.

Based on perception studies, it is known that infants and young children are sensitive to prosodic phrasing. American infants were shown to use prosodic boundaries (PhP boundaries) to constrain lexical access, between 10 and 13 months (Gout et al. 2004). Later work by Millotte, Morgan, Margules, Bernal, Dutat, & Christophe (2010) showed that French infants, when tested in the same paradigm, demonstrated sensitivity to phonological phrase boundary cues at 16 months.

Männel & Friederici (2009) used neurophysiological measures through ERP to study the processing of intonational phrase boundary cues by German 5-month-olds and by adults. The results indicated that infants respond to sentence internal IP boundary when it is marked by a pause. As for adults, they responded even when the pause was eliminated, while other prosodic cues to the boundary were preserved.

A further aspect of the impact of prosody that has been investigated is the location of a word in the sentence. Seidl & Johnson (2006) looked at the effects of word location to test their *Edge Hypothesis*. The authors assume that "infants use utterance edges to help them locate words in fluent speech". Looking at the acoustic cues, utterance edges are prosodically prominent. Results from 8-month-old English learners demonstrated significant differences between edge final/edge initial and utterance middle positions, indicating that infants were able to segment words placed at edges, but not in utterance internal position. A follow up of this work has found segmentation at edge position by infants as early as 6-months (Johnson, Seidl, & Tyler, 2014). Relating these results with previous findings, it is clear that each edge is marked by a pause (a silence), and in these studies the prosodic boundary properties were not investigated. As pointed out in Dahan, & McQueen (2003), considering that the recognition of a spoken word proceeds incrementally, as soon as acoustic information becomes available, the speech signal contains cues resulting from the realization of prosodic boundaries, and words that are aligned with such boundaries are favored in the process that leads to word segmentation and recognition (Christophe, Gout, Peperkamp, & Morgan, 2003).

Overall, the available work indicates that the development of linguistic abilities attuned to the native language starts around the second semester of life. These abilities are extremely important, as it has been suggested that they have an impact on later language development, namely at the vocabulary level (Newman, Ratner, Jusczyk, Jusczyk, P. W., & Dow, 2006; Tsao, Liu, & Kuhl, 2004).

Speech segmentation is also relevant in later stages of language processing, for instance, for lexical and syntactic ambiguity resolution. Most studies on this topic looked at the resolution of structural ambiguity related to ambiguous attachment of syntactic constituents and lexical parsing. Studies on attachment preferences have focused on the description of the processing of ambiguous sentences, that may have different syntactic analyses which in turn can be associated to different interpretations, as shown in the following example with a relative clause (Cuetos & Mitchell, 1988):

(1) Someone shot the servant$_{NP1}$ of the actress $_{NP2}$ *who was at the balcony* $_{\text{relative clause.}}$

In this sentence, the relative clause can refer to *the servant* (NP1) or to *the actress* (NP2). In the first case there is a high (or non-local) attachment structure, whereas in the second case there is a low (or local) attachment structure. In terms of sentence processing, attachment preferences were described as associated to parsing strategies: Late Closure, when the ambiguity is solved later during ambiguous sentence processing, as in the case of a low attachment preference; and Early Closure, when ambiguity resolution happens earlier, as in high attachment preference (Speer, Kjelgaard & Dobroth, 1996). The integration of prosody into processing models became crucial to account for sentence parsing. The first experimental studies, involving silent reading, were based on the Implicit Prosody Hypothesis (IPH), where readers project prosodic properties into sentences, as the processing of syntax and prosody occurs in parallel, influencing structural ambiguity resolution (Fodor, 1998). A certain prosodic organization presents its own constraints, as it can be motivated by an optimal prosodic phrase length or by a syntax-prosody alignment (Fodor, 2002). To illustrate this difference, the author presents a cross-language comparison between French and English, where the insertion of a break before a long relative clause in French is demanded by length prosodic rules, but it does not affect attachment preferences, whereas the same phenomenon in English favors a high attachment interpretation (long relative clause refers to NP1). The role of implicit prosody in sentence processing has been largely studied, widely focused on silent reading (see Breen, 2014 for review). The influence of prosodic phrasing in sentence processing is well known, and it has been suggested that the differences among languages may also reflect the specificities of each language prosodic structure (Jun, 2003; D'Imperio, Elordieta, Frota, Prieto, & Vigário, 2005; among others).

As for lexical parsing, sentence processing involves segmentation of words in the speech stream and access to its lexical representation. In case of ambiguity, sentence parsing is confronted with a conflicting lexical hypothesis, involving the activation of multiple competing candidates. The edges of prosodic constituents are always aligned with word boundaries, and the properties that assign prosodic levels are known to facilitate the recognition of word boundaries. For example, Davis, Marslen-Wilson, & Gaskell (2002) looked at target words acoustic differences (prosodic cues such as syllabic duration) for word recognition, as in the cases illustrated in (2)

(2) TRACK–TRACTOR

(a) When it reached the house, the ***track tur***ned north towards the forest.

(b) When it reached the house, the ***tractor*** came to a halt.

In sum, the investigation has shown that adults make use of prosodic phrasing to facilitate lexical and syntactic interpretation, both in production and perception (Speer, Kjelgaard , & Dobroth, 1996; Ferreira & Dell, 2000; Schafer, Speer, Warren, & White, 2000; Carlson, Clifton, & Frazier, 2001; Watson & Gibson, 2004 Nakamura, Arai, & Mazuka, 2012; Dahan, 2015, for a review)

The impact of prosody on lexical and syntactic processing has also been studied in children. For Korean, Choi & Mazuka (2003) concluded that 3-to-4 year old children use prosodic cues for sentence parsing in the case of lexical ambiguity resolution, but are unable to resolve syntactic ambiguity, even by age 5-6. This study confirmed the use of prosodic phrasing cues in speech processing by young children, while also showing that the same cues that are successful in lexical disambiguation could be unsuccessful in syntactic disambiguation, suggesting that the syntactic knowledge required for syntactic disambiguation evolves later than lexical knowledge, and then prosodic knowledge. Other studies also point to children's failure at syntactic disambiguation. Testing an older population, namely I6 year old Irish children, Wiedmann and Winkler (2015) show that at this age individuals are able to use prosodic means for disambiguation and make use of the same processing mechanism as adults. Testing 4-to-6 year old English learners, Snedeker & Yuan (2008) addressed attachment preferences by children. This research intended to understand the development of syntax/prosody alignment in language acquisition. They were able to show children's ability to integrate prosody to constrain syntactic analysis by age 5, relying on prosodic cues as adults do. Recent studies testing French and American English children reported their ability by age 4 (or even early) to use prosodic phrasing in syntactic disambiguation (De Carvalho, Dautriche, & Christophe, 2016a; De Carvalho, Lidz, Tieu, Bleam, & Christophe, 2016b). According to Isobe (2007) Japanese-learning children can use prosodic information to disambiguate syntactically ambiguous sentences as young as 3 years old. These differences in results across languages leave open two questions: how prosodic phrasing cues are used in interaction with lexical and syntactic analysis in the process of sentence parsing in EP and at what age does disambiguation occur.

For EP, research on longitudinal production data indicates that initial productions of single disyllabic words are treated as, or correspond to, two prosodic words and two intonational phrases and, only later, each syllable stops to both match a PW and IP (Frota, Cruz, Matos, & Vigário, 2016). For example, it is observed that when attempting the production of disyllabic targets, the child produces each syllable with a pitch accent, like a PW in IP nuclear position in the adult system, and only later is there a single pitch accent associated to (the prominent syllable of) the PW.

Like in other languages, the prosodic structure of EP is signaled by a constellation of cues. The PW is the domain of word stress and related processes, such as vowel reduction, edge-phenomena like phonotactic constraints, and many segmental and prominence cues (Vigário, 2003a). The next level in prosodic hierarchy, the prosodic word group (PWG) is also marked by segmental processes and prominence (Vigário, 2010). By contrast, the PhP is weakly marked, although it plays a functional role in rhythmic phenomena and pitch accent distribution (Frota, 2000; 2014). The PhP is not cued by tonal or durational phenomena in EP, such as an obligatory pitch accent or tonal boundary, or phrase final lengthening, or initial strengthening. By contrast, a variety of cues marks the IP: segmental processes, sandhi and resyllabification (similar to other Romance languages), final lengthening and pause, left-edge strengthening, pitch accent distribution, the nuclear pitch accent and boundary tone (Frota 2000, 2014). In sum, word level boundaries and IP boundaries are the prosodic breaks signaled by a larger set of cues.

Overall, investigations in the last decades have highlighted the importance of prosody in language acquisition and language processing. Studies on the acquisition of different languages have revealed age differences in infants' sensitivity to prosodic information relevant for lexical access and syntactic analysis. Studies on the role of prosodic phrasing in disambiguation have looked more to higher (PhP and IP) than lower prosodic levels and cross-linguistic comparison is still lacking. For early word segmentation, studies on different languages, focused mostly on word shape and word stress, and less on the role that prosodic structure may play. Taking this into consideration, the work presented here aims to probe the role of phrasal prosody in various linguistics abilities, in the process of language acquisition: syntactic analysis, lexical access and word segmentation. Although the focus of our studies is on the early years of acquisition, adult data provides baseline information to look at the process of acquisition and its developmental path.

The existence of differences across languages also constitutes crucial motivation for the present research. European Portuguese provides a test case for the study of the role of prosody in early segmentation of speech and in lexical and syntactic processing as shown in ambiguity resolution. This language combines prosodic properties of two well studied groups of languages, namely Romance and Germanic languages, and thus may contribute to the understanding of the effects of language-particular properties on the course of linguistic development.

In the following chapters, we present a series of experimental studies. Chapter 3 reports on a first exploratory study where we address the use of prosody phrasing in syntactic analysis by adult native speakers though the resolution of global ambiguities. This study aimed to clarify how prosody and its properties might influence syntactic attachment decisions in the language

The two experimental studies, reported in chapter 4, respectively examined adult and 4 and 5-year-old children's use of phrasal prosody in the parsing of globally ambiguous sentences where differences in phrasal prosody are triggered by the syntax-prosody interface and part of the common, default prosody of the sentences. With this study, we intended to test the role of the contrast between two prosodic levels – Prosodic Word and Intonational Phase. As we mentioned above, in EP, both PW and IP breaks are signaled by several cues, and thus we expect an effect of such a phrasal prosody contrast in sentence parsing.

The two last experimental studies, described in chapter 5, focus on word segmentation abilities in 12-month-old monolingual Portuguese learners. The goal was to establish how prosodic phrasing contributed to word segmentation and clarify which prosodic level cues might be involved. Here, we were interested in word segmentation abilities in utterance internal position, and also contrasted PW and IP boundaries. Given the reported early perception of utterance breaks by infants, we expected to observe word segmentation at IP utterance internal breaks by at the end of the first year of life. However, IP prosodic cues were restricted to pitch and durational cues, since no pause cue was present in the stimuli. If 12-month-olds have fully developed their segmentation abilities, they should be able to demonstrate segmentation in either prosodic condition; if phrasal prosody constrains early word segmentation beyond the utterance edge, then infants are expected to perform better at the IP condition.

With these series of studies, we hope to contribute to our knowledge of (i) the role played by different boundary levels and boundary cues in speech segmentation and (ii) to the understanding of the developmental path of the abilities to exploit phrasal prosody in language acquisition.

3 Exploratory-pilot study: Phrasal prosody and syntactic ambiguity (Adults)

3.1 Introduction

The role of prosodic phrasing in disambiguation has been subject to little investigation in European Portuguese (EP). In this chapter we review the work done in this area in EP and other languages, identify some of the major research questions in this domain and report on an exploratory pilot study conducted for this thesis. As our goal was to examine the role played by phrasal prosody in language acquisition and development, in this pilot experiment we investigated whether and to what extent prosodic phrasing impacted adult listeners' ability to disambiguate syntactically ambiguous sentences involving a low or high attachment interpretation of a given phrase. This exploratory study thus aimed to address previously unsettled issues on the role of prosody in the adult system that is targeted by infants acquiring EP.

The use of prosodic boundary cues in the processing of both lexical and syntactic ambiguity has been reported for several languages. Research on how prosodic phrasing may guide speech chunking and interpretation of utterances has looked, for instance, at the relation between prosodic structure and constituent attachment, which in turn relates to syntactic categories and functions. Let us look at the following example, for English:

(1) Hide the rabbit with a cloth.

It is known that in English, in a sentence like (1), the presence of a high level prosodic boundary, namely an IP boundary, between the noun and the prepositional phrase (i.e. (*Hide the rabbit*)$_{IP}$ (*with a cloth*)$_{IP}$) favors high attachment interpretation where *with the cloth* is interpreted as an instrument. By contrast, the presence of a low level prosodic boundary, namely a PhP boundary at the same location (i.e. (*Hide the rabbit*)$_{PhP}$ (*with a cloth*)$_{PhP}$), or of an IP boundary between the verb and the noun (i.e. (*Hide*)$_{IP}$ (*the rabbit with a cloth*)$_{IP}$) favors low attachment interpretation, in which case *with the cloth* is interpreted as a modifier of the noun (e.g. Watson & Gibson, 2004; Snedeker & Trueswell, 2003 Price et al., 1991).

In EP, a language with particular prosodic properties, as described in the previous chapter, only a few studies have investigated this topic. Vigário (1997b; 1998; 2003b) reported on a number of globally syntactically ambiguous structures where prosodic phrasing at the level of the IP and PhP is, or may be used, for disambiguation. The structures observed involve the direction of attachment of adverbs (where the element modified is either to the right or to the left of the adverb, as in globally ambiguous sentences like 'Os rapazes **apenas** emprestaram livros às raparigas' *The boys have only lent books to the girls/ Only the boys have lent books to the girls*), high *versus* low attachment of prepositional phrases and adverbs of different classes, including those investigated in Frota (1991), and explanatory *versus* restrictive relative clauses. These constructions were investigated on the basis of linguistic intuitions, production data in felicitous eliciting contexts, and a small perception study testing prosodic disambiguation. Overall, it was found that not only IP but also PhP boundaries may be used in prosodic disambiguation, but prosodic phrasing does not always trigger disambiguation.

Vigário (2003b) addressed the relation between prosodic phrasing and syntactic structure on the three types of globally ambiguous sentences mentioned above, on the basis of production data. Similar to English, in EP prepositional phrases (PP) can be interpreted either as a modifier of the preceding noun (low attachment) or have an instrument interpretation (high attachment). Sentences with ambiguous PP were shown to exhibit several prosodic realizations depending on the interpretation triggered by a preceding context-sentence:

(2)

a) ((A Joana) $_{\text{PhP}}$ (observou) $_{\text{PhP}}$ (o rapaz) $_{\text{PhP}}$ (com os binóculos))$_{\textbf{IP}}$

'Joana saw the boys with the binoculars'

b) (A Joana) $_{\textbf{IP}}$ ((observou) $_{\text{PhP}}$ (o rapaz) $_{\text{PhP}}$ (com os binóculos))$_{\text{IP}}$

c) ((A Joana) $_{\text{PhP}}$ (observou)) $_{\textbf{IP}}$ ((o rapaz) $_{\text{PhP}}$ (com os binóculos))$_{\text{IP}}$

d) ((A Joana) $_{\text{PhP}}$ (observou) $_{\text{PhP}}$ (o rapaz)) $_{\textbf{IP}}$ (com os binóculos)$_{\text{IP}}$

Sentences like (2a) are usually phrased as a single IP. The insertion of internal IP breaks, as observed in other languages like English, may be motivated by phonological and/or syntactic reasons. An IP prosodic break as in (2b) is optional, and usually more commonly observed due to constituent length effects (see below), or for subject enhancement. In both cases, however, the prosodic phrasing does not disambiguate PP attachment. An IP boundary between the verb and its complement as in (2c) can be triggered by prosodic balance considerations. Differently from (2c), the IP break before the PP in (2d) cannot be triggered by phonological reasons, but only by syntactic reasons. The author argues that syntactic parsing must be involved to justify IP break in (2d), and that, together with prosodic balance, it may be involved in the phrasing in (2c). In (2d) the prosodic phrasing favors the high attachment interpretation of the PP; in (2c) it favors the low attachment interpretation. Therefore, EP is described as following the English pattern, where a high level prosodic break between the noun and the PP as in (2d) favors the high attachment reading, and keeping the noun and the PP inside the same IP phrase favors low attachment.

Vigário (2003b) also observed that non-restrictive relative clauses may be ambiguous with respect to their antecedent (as in 'A amiga da Joana que vive em Coimbra' *The friend of Joana who lives in Coimbra*), which could be the locally adjacent NP ('Joana') or the non-local antecedent ('a amiga'). However, the presence of an IP break before the non-restrictive clause strongly favors a non-local reading over the local interpretation.

In other studies involving processing of relative clause attachment, Maia, Fernández, Costa, & Lourenço-Gomes (2007), using a self-paced reading task, showed that on-line results pointed to an initial advantage for the low attachment reading, with longer reaction times when materials forced high attachment. On the other hand, a preference for high attachment interpretation was observed when participants answered reading comprehension questions in an offline task, showing more errors when the materials forced low attachment. However, it is important to note that in this study prosody was not fully controlled. Nevertheless, these results suggest that, as already pointed out in Watson, Wagner, & Gibson, (2012), among others, attachment preferences seem to vary depending on the type of task, and both within and across languages.

More recently, a set of experimental studies was systematically conducted to examine the role of phrasal prosody in locally ambiguous sentences (Frota et al., 2010, Severino 2011). In Frota et al., (2010) not only the effects of high-level prosodic boundaries as IPs were investigated, but the full range of prosodic boundaries type was tested, from word level to phrasal level. Four experiments were conducted, two of which were off-line tasks (a listening completion task and a reading completion task) and the other two were on-line tasks (a word detection task and an eye-tracking task). The authors defined their predictions based on the systematic descriptions of the prosodic structure of European Portuguese (Vigário, 2003a, 2010; Frota 2000, 2014, Elordieta, Frota, & Vigário, 2005). Based on the phonological properties of each prosodic level, it was predicted that adult listeners might be able to exploit word level boundaries (PW) and IP boundaries for disambiguation, since these constituents are cued by clusters of phonetic and phonological phenomena (see Chapter 2 – Background). The prediction was not as clear for the PhP boundary, since this is described as weakly marked in the language. The different experimental approaches provided slightly different results, offering a large spectrum of information.

In general, Frota et al., (2010) and Severino (2011) showed that listeners rely on different prosodic level cues to constrain lexical and syntactic decisions. In the absence of overt prosodic cues, as it happens in a reading completion task, the results showed a default processing strategy that reflected a preference for the low attachment interpretation, which was found in the materials from all prosodic levels. In the presence of overt prosodic cues, the results from the on-line tasks showed a higher sensitivity to prosodic cues to word-level distinctions (e.g., [passatempos] *hobbies* versus [passa] [tempos] *spend time*) than those of off-line tasks, which yield no disambiguation at the lexical level. It was found that the contrast between a word-level boundary and a PhP boundary was perceived by listeners, especially in on-line tasks. Finally, the main results showed a clear effect of the presence of an IP boundary on disambiguation. This effect was however modulated by constituent length when the two phrasal levels (PhP/IP) contrasted. Only long but not short constituents triggered disambiguation (>6 syllables). According to Frota et al. (2010), this type of effect in sentence parsing may be related to the length effect previously observed on IP phrasing in production, namely the tendency in Standard EP to break SVO sentences into two major phrases, yielding the prosodic phrasing (S)(VO), when the subject of the sentence is longer than 5 syllables (Elordieta, Frota, & Vigário, 2005). Furthermore, Elordieta et al. (2005) showed that the longer the first constituent in the sentence is, the stronger the tendency to phrase it separately as an IP. Along the same lines, the findings from Frota et al. (2010) and Severino (2011) showed that constituent length affected how listeners used phrasal prosody: if the IP was short, it might not be differentiated from the PhP, and thus disambiguation might not occur, whereas the cues for IP boundaries after long constituents always had a clear disambiguating role. By and large, these studies demonstrated that EP listeners are able to use prosody in disambiguation, but results may vary depending on the type of task and other factors, such as constituent length. Overall, these results indicate that more investigation is needed in order to better understand the adult system that is targeted by children acquiring EP.

In order to further study, and clarify, the role of phrasal prosody in disambiguation in EP, we have set up an experiment where we tested adult subjects with sentences that showed global ambiguity, similar to the *tap the frog with the feather* utterances used, for example, in the study by Snedeker & Yuan (2008) for English. Notably, Snedeker & Yuan showed that English-learning 5-year-old children could successfully use prosody to interpret these ambiguous sentences, like English adults do (Watson & Gibson, 2004, Snedeker & Trueswell, 2003; Price et al., 1991). The main purpose of this experiment was to better understand the role of phrasal prosody in sentence processing in EP. To this end, we used sentences like those in (2) above (akin to the English examples in (1) and in Snedeker and colleagues studies) and tested three of the prosodic phrasing contrasts described in Vigário (2003b): sentence phrased as a single IP, IP break after the verb and IP break before the PP. Given previous findings on the disambiguating role of IP boundaries, both in production tasks and language comprehension tasks (Vigário, 1997b; 1998; 2003b; Frota et al., 2010; Severino, 2011), it is predicted that listeners will be able to use prosodic information for disambiguation. Furthermore, since the sentences have enough material before the IP boundary to control for constituent length effects, it is expected that IP breaks will be perceived. However, previous studies have also highlighted the presence of biases in interpretation independently of prosody (Maia, Fernández, Costa, & Lourenço-Gomes, 2007), and the optional nature of some of the IP boundaries produced given an intended reading (Vigário, 2003b). This leaves open the effect of IP boundaries in the parsing of globally syntactic ambiguous sentences. It is critical for us to clarify whether adult EP listeners make use of phrasal prosody to process ambiguous sentences, before we set out to investigate the topic in language acquisition. This is the main goal of this pilot study.

3.2 Method

- *Participants*

Twenty native Standard European-Portuguese speaking adults (mean age: 24,9; min. 19; max. 34), all monolingual, were tested at the Lisbon Baby Lab facilities, in the University of Lisbon. They all reported no hearing problems and none of them was aware of aims of the study. Two other participants were excluded due to a visual deficit that required the use of eye-contact lenses or glasses with thick lenses, which made gaze capture impossible with the eyetracker.

- *Materials*

Two sets of sentences with global ambiguity were created, which only differed in their prosodic structure. The key prosodic contrast was a Phonological Phrase boundary (PhP), that is a low phrasal boundary, or an Intonational Phrase boundary (IP), that is a high phrasal boundary, at the same location. For each set, three test sentences and a control sentence were created: the sentence produced as single IP (3), thus including a PhP break at the relevant location (Low boundary condition); the sentence produced with an IP break, marked with a pause, after the verb (4), and expected to trigger a low attachment interpretation (Lowp boundary condition); the sentence produced with an IP break before the PP (5), expected to trigger a high attachment interpretation (High boundary condition); an ambiguous sentence, as in (6) (Control condition).

(3) Low:

1a) O Tito tira$_{php}$ o balão$_{php}$ com o pau.

2a)O Tito anda$_{php}$ de baloiço$_{php}$ e escorrega.

(4) Lowp:

1a!) O Tito tira$_{ip}$ o balão$_{php}$ com o pau.

2a!) O Tito anda$_{ip}$ de baloiço$_{php}$ e escorrega.

(5) High:

1b) O Tito tira o balão$_{ip}$ com o pau.

2b) O Tito anda de baloiço$_{ip}$ e escorrega.

'Tito takes the balloon that has a stick (low attachment)/using a stick (high attachment)"

Tito played on the swing and on the slide (low attachment)/on the swing set and fell (high attachment)"

(6) Control:

1c) O Tito tira o balão verde 'Tito takes the green balloon"

2c) O Tito anda de baloiço no recreio. "Tito played on a swing in the playground"

The prosodic boundary level adjacent to the target sequence is expected to disambiguate the meaning at least in some cases. In particular, given the algorithms for prosodic phrasing in EP (Frota 2000, 2014), it is expected that sentence (3) may allow either reading, and preferred readings might be observed if there are language-specific attachment preferences. The major break after the verb in (4) is not motivated by syntax. However, the result yields balanced IPs and thus this break may be prosodically motivated. The fact that both the NP and the PP belong to the same IP, which is different from the previous IP, may indicate that this IP constitutes a sense unit different from the sense unit delimited by the previous IP (Frota, 2000; Selkirk, 1984), and for that reason high attachment is expected to be blocked. Notice that in English both (3) and (4) have been shown to yield low attachment interpretation (Watson & Gibson, 2005, Price et al., 1991). We may therefore put for the hypothesis that if a preference emerges in these cases it will be in favor of low attachment also in EP. An IP break before the PP, or de coordinate phrase, as in (5), is in principle not well formed on a purely phonological basis, since the result is a short IP at the left edge of the utterance. This, together with the generalization that holds in EP, like in other languages, that the relation between heads and adjacent complements or modifiers should not be prosodically broken, make it expectable that this break is only compatible with the high attachment syntax and interpretation.

To exclude any residual cues related to lexical frequency or syntactic structure that could have an impact on sentence processing, besides the phrasal prosody, we decided to include only unmarked and simple syntactic structures, common in adult speech and especially child-directed speech, and a lexicon that is already present in child speech at the early ages of language development. Thus our materials included words that not only are highly frequent in the language, but also are part of a speakers' lexicon since the early stages of word acquisition. It is well reported the importance of early acquired word effects and its consistency across languages. Early acquired words are processed faster and easier, and they are also less affected during aging and neurological disorders (Cameirão & Vicente, 2010; Monaghan, 2014). The use of children's vocabulary also allowed the replication of the same experiment with young children, as planned when we decided to conduct this pilot experiment. Vocabulary selection was made using available databases for adult speech (MorDebe[1], and the FreP[2] tools and database) and child speech in European Portuguese (CHILDES: Child Language Data Exchange System; PLEX5: A production lexicon of child speech for European Portuguese) and the data from the EP MacArthur-Bates Communicative Development Inventory Short Form for level II normative study (Frota, Butler, Correia, Severino, Vicente, & Vigário, 2016). The words selected were present at least in one of the databases previously mentioned in the speech of children since age 2;06. As for the syntactic structure, we have used simple short declarative sentences. All sentences exhibited EP canonical word order. Studies performed based on spontaneous speech and experimental tasks eliciting word order report the acquisition of SV pattern with transitive verbs in EP as early as 2;01 years of age, revealing a strong preference for this type of structure by children (Costa, 2000; Friedmann & Costa, 2011). The kinds of structure used in the experiment were also commonly found in the CDS-EP database[3] (Frota S., Cruz, Martins, & Vigário, 2013). In short, not only the lexicon but also the type of syntactic structure are common in the language and are found from the early stages of language development. A control unambiguous sentence completed the set, following a structure similar to the ambiguous.

A trained female speaker produced the utterances, and recordings took place at the Lisbon Baby Lab, with a sampling rate of 44100hz, 16 bit, and mono channel. Acoustic analyses were performed for tonal events, pitch range, pitch reset, syllable duration (stressed syllable and post-stressed syllable immediately preceding the target prosodic boundary) and pauses (when present), to identify the exact acoustic cues for phrasal prosody (3.1). The analysis of pitch and duration, as well as pause distribution, revealed clear differences across the prosodic conditions tested, with the presence of an IP boundary being signaled by larger pitch range before the boundary, due to the nuclear contour, and longer duration due to phrase-final lengthening. The IP boundary, unlike the PhP break, is also signaled by a pause, and pitch reset, consistent with previous literature (Vigário 1998, Frota 2000, 2014).

[1] http://www.portaldalinguaportuguesa.org/?action=mordebecontent
[2] http://labfon.letras.ulisboa.pt/FreP/tools.html
[3] http://labfon.letras.ulisboa.pt/babylab/english/CDS_EP.html

Table 3.1: Acoustic analyses

Boundary 1 (after Verb)

Boundary	sentence length (ms)	syllable duration_before boundary (ms)		pitch range (hz)		pitch reset (hz)	pause duration
		S1	S2	S1	S2		
Low average	1985	163	117	25,3	4,75	13,15	.
standard deviation	205,06	4,2	26,9	7,64	26,66	22,27	.
Lowp average	**2324**	**250**	**211**	**55,3**	**111,15**	**69,6**	**178**
standard deviation	**189,5**	**9,9**	**16,3**	**22,34**	**1,63**	**37,34**	**100,4**
High average	2397	144,5	111	24,75	7,6	3	.
standard deviation	120,2	40,3	29,0	7,71	24,18	20,08	.

Boundary 2 (after Noun)

Boundary	sentence length (ms)	syllable duration_before boundary (ms)			pitch range (hz)			pitch reset (hz)	pause duration
		S1	S2	S3	S1	S2	S3		
Low average	1985	166,5	222,5	151	5,6	17,15	13,60	15,3	.
standard deviation	205,06	16,26	13,44	.	11,17	28,21	.	28,57	.
Lowp average	**2324**	155,5	207	160	7,05	8,8	4,10	17,05	.
standard deviation	**189,5**	3,54	53,74	.	6,86	7,64	.	23,41	.
High average	2397	**156**	**365**	**205**	**52,3**	**3**	**15,10**	**84,70**	**272,5**
standard deviation	120,2	**12,73**	**144,25**	**.**	**87,82**	**49,21**	**.**	**32,95**	**67,2**

Recordings were edited to create individual sound files (duration: mean 2138ms, max. 2482ms, min. 1680ms) with 100ms silence at the onset and 50ms at the offset. This avoided sound-picture desynchronization during software trial loading.

For each sentence, a picture matching the sentence description was created. Therefore, for each set of test sentences we had two pictures, one matching the low attachment interpretation and another matching the high attachment interpretation. Pictures of the same set were then presented in pairs together with a sound stimulus in counterbalanced positions (left/right and right/left). During testing, the picture representing low attachment interpretation was labeled as the target picture and the picture representing the high attachment interpretation as the non-target picture in the low and lowp prosodic conditions; in the high prosodic condition, we have the reverse pattern. In the case of the low condition, we put for the hypothesis that if a preference emerges it will be for low attachment interpretation, as previously observed for English.

A pilot test for picture validation was performed with adults and children (10 undergraduates, aged 19-25 years old; 10 children, aged 3-5 years old), as a way to control for the imageability and validity of interpretation regardless of the age of the subjects. For picture validation, participants heard the sentences and were asked to tell if any of the pictures matched and if so which picture matched. The pilot test was set using a PowerPoint slideshow, each slide containing pairs of pictures and a sentence sound file. No sound replay was needed, since participants were able to answer immediately. One of the control sentence pictures ('o tito gosta do boneco' *Tito loves the doll*) had to be replaced due to an object/noun misrepresentation. Children interpreted the word 'boneco' (doll) as any toy representing a living figure, human or animal. This made a butterfly also a potential target object, and thus children considered both options valid in the picture in Figure 1.1.

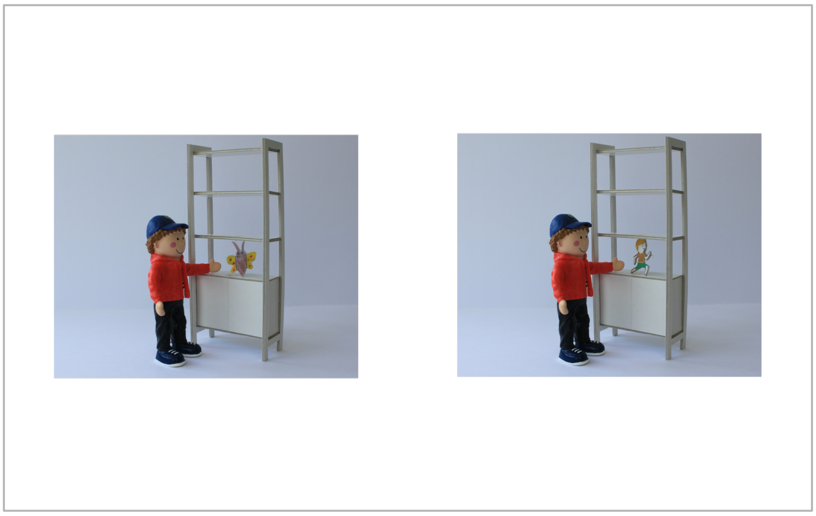

Figure 3.1: Example of the picture replaced after pilot testing for image validation.

For the experimental design, we followed the trial outline used in Brandt-Kobele & Hohle (2012), where eye gaze at presented pictures was tracked before and after the presentation of the stimulus sentences in every trial. A pointing task was added at the end of each trial. Specifically, we have asked the subjects to point with their finger to the picture that was congruent with the meaning of the sentence they listened to (Figure 3.2). This would allow us to verify whether the initial sentence interpretation was revised, and evaluate if differences in results reported by Maia et al (2007) for attachment preferences in EP might be due to working memory effects (Vuong & Martin, 2014; Woodard, Pozzan, & Trueswell, 2016).

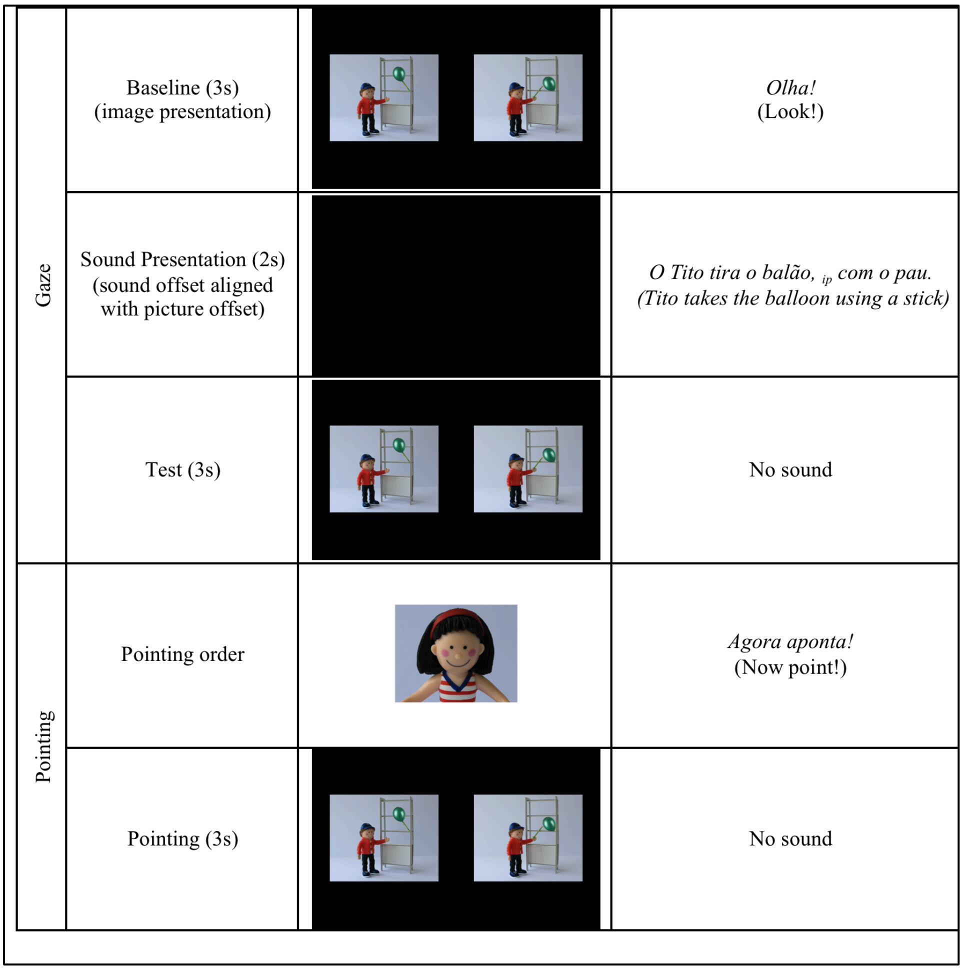

Figure 3.2:Experimental trial design

Two experimental blocks were created, so that Low and High conditions within a sentence set appeared separately in each block. As for the Lowp condition, it was included in the same block together with the High condition. In this way, each block contained sentences of each prosodic condition and respective controls. Since we counterbalanced for picture side, each sentence was presented twice (Table 3.2).

Table 3.2: Experimental condition settings and sentences distribution.

	Phrasal Level			
	block 1		**block 2**	
Trial Nr	**sentence**	**Target picture side**	**sentence**	**Target picture side**
	Training_1	right	Training_1	right
	Training_2	left	Training_2	left
1	1c	left	1c	left
2	2c	right	2c	right
3	2a!	right	1a!	right
4	1a	left	2a	left
5	2b	left	1b	left
	interval video	**interval video**	**interval video**	**interval video**
6	1c	right	1c	right
7	2b	right	2a	right
8	2c	left	2c	left
9	1a	right	1b	right
10	2a!	left	1a!	left
	Reward video	**Reward video**	**Reward video**	**Reward video**

A block included a task introduction with two training trials, all test trials and two animated videos for interval and task reward at the end. Testing started with two control items, followed by a pseudo-randomized presentation of trials. Pseudo-randomization avoided consecutive presentation of items of the same prosodic condition. Each trial was composed of 2 phases: a gaze phase and a pointing phase. The gaze phase was used to inspect subjects' proportion of look to images (target *vs* non-target) before and after sentence presentation. The pointing phase helped to crosscheck gaze and to see if subjects would eventually reformulate their decision at late offline processing. In the case of ambiguity resolution, participants should look longer to the correct (target) picture. Eye movements were automatically tracked by a remote eye-tracking system (SMI RED500), which measured task performance.

- *Procedure*

Subjects were tested individually and filled an informative report before testing. Before the experiment started, the experimenter informed participants that instructions would be given at the onset of the experiment and they just needed to pay attention to what they would see and hear. Participants were comfortably seated in front of the monitor at a distance of approximately 70 cm, and sound stimuli were presented through headphones

(Sennheiser HD). A 5-point calibration was followed by a 4-point validation for eye-tracking accuracy.

The experiment started with a doll asking the participant to help her in a game and introducing two characters, *Tito* and *Vera*. The doll says that Tito does many things. Vera likes to talk about Tito's adventures and to show pictures. In order to help her, participants need to show which is the picture that matches the sentence they will hear. The doll gives instructions with a step-by-step explanation of the trials using training examples. After two training trials with feedback, testing starts. Each trial is composed of 5 events (Figure 3.2). Trials begin with the first presentation of the pictures placed side by side, with a sound reinforcer (*Olha!* 'Look!'). The monitor then turns black and sentence presentation starts aligned with event onset. At the offset of the sentence, the two pictures reappear pairwise on the screen and gaze registration takes place. In the fourth event, the doll image asks the participant to point to the correct picture and, finally, the same pairwise pictures are presented for the third time for pointing registration.

- *Data processing*

The SMI RED 500 Eye Tracker software package was used for experiment setting, gaze data registration and extraction. For subject's gaze data, recorded with a 60Hz tracking resolution, two Areas of Interest (AOI) were defined on the paired pictures – target and non-target - both on baseline events and test events. Gaze data during pointing events were not analyzed since pointing movements affected gaze data collection (the tracking camera was in general temporarily blocked by the subject's arm). AOI's net dwell time values[4] were used as gaze measurement. For statistical analysis, we calculated the proportion of net dwell looking time at pictures matching the high attachment interpretation and used it as the dependent variable. In order to inspect visual behavior over the test phase time course according to prosodic condition, graphs with the proportion of looks were plotted. As for the pointing data, subjects' pointing direction was registered during the experiment through the system's video camera (left/right). Coding was performed offline, using the video recordings. For this, only pointing task events were considered for analysis. The hits to target picture were then coded on each trial and used as dependent variable for statistics. Data processing first started with pointing data coding. Pointing errors to control trials were used as subject exclusion criteria, since we considered this has an indicator of task performance inability or a signal that the participant was distracted. No subjects were excluded from data analysis.

[4] Net dwell time includes the sum of durations from all fixations and saccades that hit the AOI.

- *Data analysis*

We ran a by subject repeated measures ANOVA over both gaze and pointing data. For gaze analysis, we included trial phase (baseline *vs* test) and prosodic condition (Low, Lowp and High) as within-subjects factors, and experimental block (version 1 *vs* version 2) as a between-subjects factor. Paired-sample t-tests were conducted to compare statistical differences between phases in each prosodic condition. For pointing data analysis, prosodic condition was used as the within-subjects factor (Low, Lowp and High) and experimental block as the between-subjects factor (version 1 *vs* version 2).

3.3 Results

- *Eye Gaze Results*

The results have shown that only the main effect of trial phase was significant ($F(1,38) = 55.866$; $p = 0.000$, $\eta^2 = .595$), showing that subjects behaved differently between baseline events and test events, a reflex of sound audio-visual processing (Figure 3.2). As for the main effect of boundary level, it was not significant ($F(2,76) = 0.198$; $p = 0.821$, $\eta^2 = .00$): regardless of prosodic phrasing, adults looked always to the picture associated to the high attachment interpretation. In other words, adults show a high attachment bias. The bias to the high attachment interpretation is clear even in the Lowp condition, where an IP boundary follows the verb and the following material forms a single IP. No main effect of experimental block was observed ($F(1,38) = 0.000$; $p = 0.993$, $\eta^2 = .000$), and no interaction was significant: phase and boundary level $F(2,76) = 2.158$; $p = 0.123$, $\eta^2 = 0.054$; boundary level and experimental block $F(2,76) = 0.742$; $p = 0.480$, $\eta^2 = .019$. Paired sample t-tests showed significant differences between phases in all prosodic levels: baseline Low (M=.483, SD=.117) and test Low (M=.752, SD=.237), $t(39)= -5.980$, p .000; baseline Lowp (M=.519, SD=.141) and test Lowp (M=.687, SD= .304), $t(39) = -3.173$, $p = 0.003$; baseline High (M=.484, SD=.152) and test High (M=.767, SD=.272), $t(39) = -6.135$, $p =0.000$. In general, gaze results demonstrated that, contrary to our predictions, a preference favoring high attachment was observed (Figure 3.3).

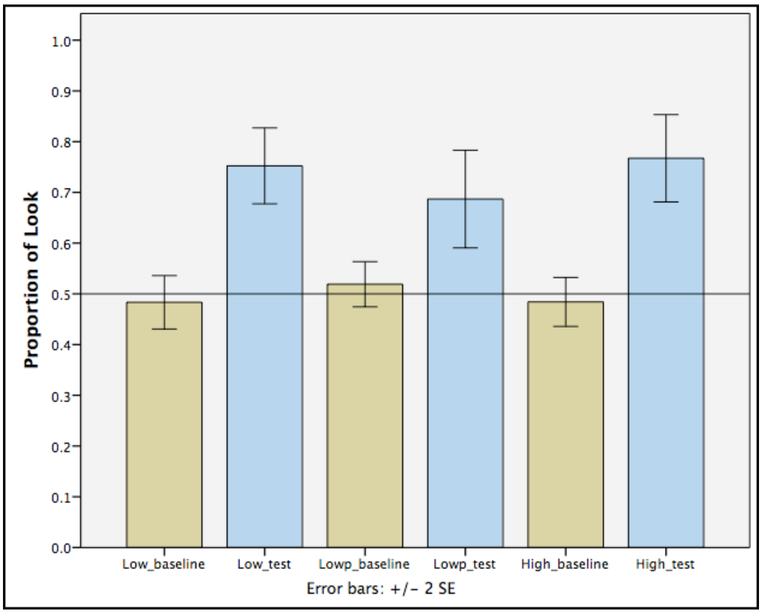

Figure 3.3: Proportion of look to high attachment image

Figure 3.4 shows the proportion of looks over test trial duration to the target pictures of each prosodic phrasing condition, plus control trials. Gaze reveals an early convergence to high attachment preference, remaining consistent throughout the test trial.

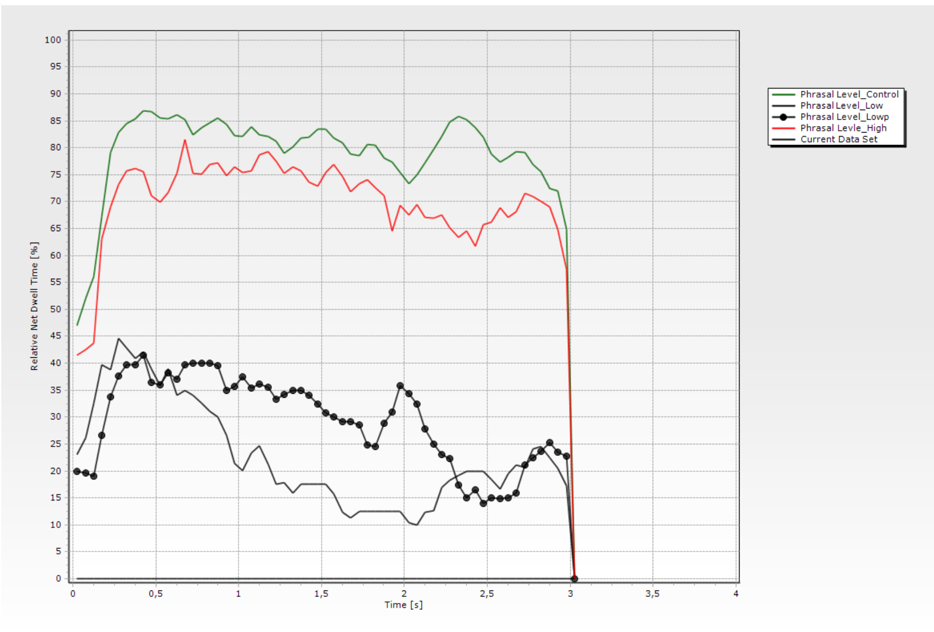

Figure 3.4: Proportion of looks to target pictures at each prosodic condition: Low is represented by a black line, Lowp by a black dotted line, High by a red line, and the control condition by a green line.

- *Pointing Results*

Pointing results follow gaze results (Figure 3.5). There is no significant main effect of prosodic condition ($F(2,36) = 0.375$; $p = 0.690$, $\eta^2 = .020$), or experimental block ($F(1,18) =$

0.240; $p = 0.630$, $\eta^2 = .013$), and no interaction ($F(2,36) = 1.982$; $p = 0.153$, $\eta^2 = .099$). This is a clear indicator of subjects' preference for high attachment, even when strong cues such as a pause preceding the object NP militate against it, as in the case of Lowp sentences.

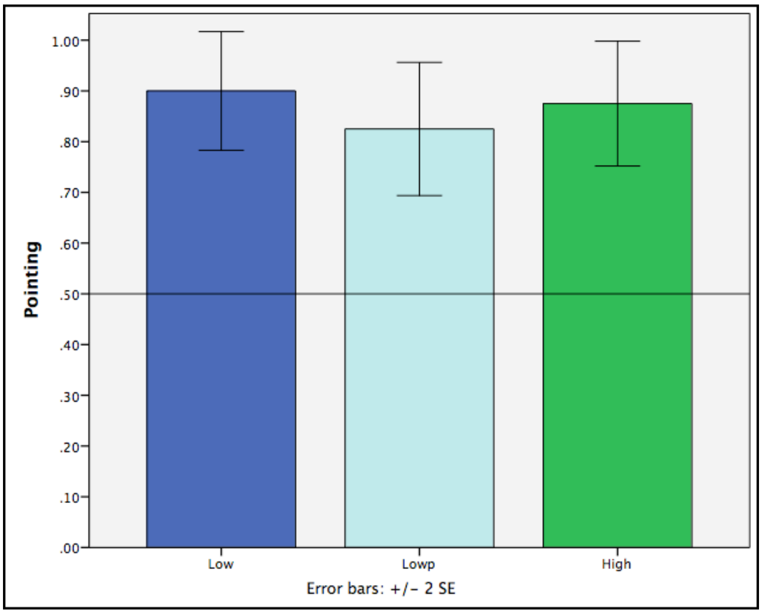

Figure 3.5: Pointing to high attachment image.

3.4 Discussion

Our results indicate the existence of a high attachment preference in the language, even in the Lowp condition, where an IP boundary follows the verb and the following material forms a single IP. Importantly, the fact that both the NP and the PP belong to the same IP, which is different from the previous IP, indicates that this IP constitutes a sense unit different from the sense unit delimited by the previous IP (Frota, 2000; Selkirk, 1984), and for this reason high attachment is expected to be blocked. Moreover, since EP does not allow an IP boundary after the verb motivated by size constraints (Elordieta et al., 2005), unlike Catalan, for example (Prieto, 2005), this prosodic break cannot be straightforwardly interpreted as simply driven by a weight effect to promote balanced IPs. EP adults thus differ from English adults (Snedeker & Trueswell, 2003), and behave similarly to some reports on English children (Snedeker & Yuan, 2008; Vogel & Raimy, 2002).

The results indicate that EP adult speakers do not seem to be able to use phrasal prosody to disambiguate the structures tested. These results are in line with the high attachment preference in offline tasks reported by Maia et al (2007). Unfortunately, the design of this experiment does not allow us to check if online sentence processing differs from offline processing and look for a potential difference in ambiguity processing during online listening. Nevertheless, data from both gaze and pointing test phases were convergent demonstrating that revision of interpretation did not occur, Furthermore, the early and consistent gaze behavior seen in our data reveals a solid decision making at the offset of a globally ambiguous sentence.

This exploratory study was conducted to examine whether adult EP listeners make use of phrasal prosody to process ambiguous sentences, using a set of structures previously studied in the literature on EP prosody, and in the literature on listeners' ability to use prosody in sentence parsing in other languages. Before we set out to investigate the topic in language acquisition, and given the unsettled issues raised in previous work, we wanted to clarify the role prosody played in the adult system that is targeted by infants acquiring EP. Our original plan was to conduct the same experiment with young children in order to assess the role of phrasal prosody in sentence disambiguation in language development. However, given the present results from EP adult speakers, it seems plausible that EP-learning children will also ignore phrasal prosody in this type of sentence and show a high attachment preference. At this point, we find that it is necessary to better understand what drives the adult interpretation of these utterances (and why EP listeners differ from English listeners, for example) before a productive study is conducted with children. A good candidate explanation for our findings is the possibility that the phrasal prosody found in these sentences is more of an optional nature, that is speakers may produce it intentionally to deal with ambiguity, but they do not have to do so because the prosodic phrasing is imposed by syntax-prosody mapping reasons. De Carvalho et al. (2016a) have suggested that this is the reason behind the apparent failure to observe effects of phrasal prosody on syntactic ambiguity resolution in English-learning children. The EP adults, therefore, show similarities with English-learning children. Taking advantage of the lessons learned from this exploratory study, we thus decided to focus on a different type of sentence with global ambiguity, namely sentences with prosodic phrasing differences triggered by the language syntax-prosody interface.

4 Young children's use of phrasal prosody in globally ambiguous sentences

4.1 Introduction

In the study reported in chapter 3, we found no effects of phrasal prosody in the processing of globally ambiguous sentences by EP adults. However, the prosodic boundaries in those sentences were optional in nature, and intentionally produced to deal with ambiguity. As it has been suggested that the failure to observe effects of phrasal prosody on ambiguity resolution may have to do with how obligatory a given prosody is in relation to the normal prosodic structure of a sentence with an intended reading (De Carvalho et al., 2016a). In the present chapter, we report experiments examining young children's (and adults) abilities to use prosody in a different sort of ambiguous sentence. We have chosen sentences with global ambiguity, which include either a compound noun followed by another noun ('guarda-chuva e pato,' *umbrella and duck*), or a list of three nouns ('guarda, chuva e pato', *guard, rain and duck*). In these sentences, the differences in phrasal prosody are directly triggered by the syntax-prosody interface, and are thus part of the default prosody of the sentence (Vigário, 2003, 2010). Thus the present chapter explores how young children, and adults, use phrasal prosody to parse these sentences and guide their interpretation.

Work developed in several languages during the past decades have shown the importance of phrasal prosody in language processing at the phonological, lexical, syntactic, semantic and pragmatic levels (e.g., Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991; Shattuck-Hufnagel & Turk, 1996; Salverda et al., 2003; Christophe, Peperkamp, Pallier, Block, & Mehler, 2004; Millotte et al., 2007; Li & Yang, 2009). In general, access to linguistic structures and meanings implies the capacity of segmenting the speech stream in order to identify word and phrase boundaries and build up linguistic structures. A hierarchical integration of cues in segmentation was proposed by Mattys, White, & Melhorn (2005). Testing both lexical and sublexical cues, the results obtained by direct comparison between cue types led to a hierarchical approach based on the relative weight of the segmentation cues (Figure 4.1). However, prosodic phrasing cues were not taken into account in this proposal.

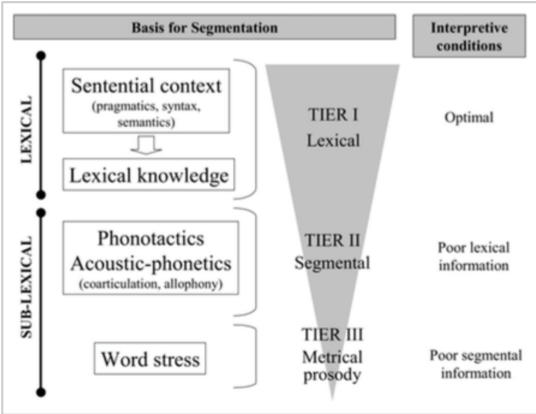

Figure 4.1: Sketch of the hierarchical weight of the segmentation cues, proposed by Mattys, White, & Melhorn (2005).

In addition, this proposal has implications for language acquisition, since those cues highly ranked in the bottom-up pyramid, such as sentential context, are not present in early phases of acquisition. The authors propose that the building up of the adult optimal system is incremental. Since phrasal prosody has been reported to constrain both lexical and sentential processing, the integration of phrasal prosody must impact the proposed hierarchy.

Given the importance that prosody plays in adult language processing, it is unsurprising that a bulk of work has been devoted to examine young children's ability to use prosody. Furthermore, the language acquisition literature has shown that infants are sensitive to prosodic information from very early on, and that prosody might help to bootstrap the learning of language (the prosodic bootstrapping hypothesis – see Morgan & Demuth, 1996; Höhle, 2009; Gervain & Mehler 2010, for a review). It is thus crucial to investigate whether and to what extent phrasal prosody can be used by young children to guide language processing. Most of this research has focused on the interpretation of sentences with global or temporary ambiguity.

A study by Choi & Mazuka (2003) revealed that 3-4 year old Korean children were able to use IP boundary prosodic cues in word segmentation in globally ambiguous sentences, where the placement of the prosodic boundary constrains word meaning,

(1) Kipper **ka**]$_{ip}$ [**pang** tiləgayo (Kipper enters (a) room)
(2) Kipper]$_{ip}$ [**kapang** tiləgayo (Kipper enters (a) bag)

Besides IP boundaries, PhP boundaries have also been shown to constrain lexical access. Data from French adults showed that the activation of a competitor word was blocked when a PhP boundary was involved, such as in the case of "… le gros **chat**]$_{php}$ [**grim**pait aux arbres", competing with **chagrin** (Christophe et al., 2004). Using an experimental paradigm involving the recognition of a familiarized word (**paper** *vs* **pay**, with **paper** competing with **pay**]$_{php}$ [**per**), Gout, Christophe, & Morgan (2004) obtained a similar PhP boundary effect with 13-month-old infants acquiring American English. This effect was also found in French-learning 16-month-olds (Millotte et al., 2010). Unlike EP, a language in which PhP boundaries only have subtle manifestations, such as rhythmic constraints and pitch accent distribution effects (see Chapter 2), PhP boundaries in French or English have been described to be characterized by initial strengthening, pre-boundary lengthening and a melodic contour (Christophe, Mehler, & Sebastián-Gallés, 2001; Keating, Cho, Fougeron, & Hsu, 2003; Delais-Roussarie, et al., 2015)

To examine young children's development in prosodic boundary processing during sentence parsing, Mannel & Friederici (2011) used event-related brain potentials (ERPs) to track the presence of a Closure Positive Shift (CPS) effect. This ERP component is related to IP boundary processing, different from obligatory ERP components that are simply elicited by a pause in the sound stream (Davis, Marslen-Wilson, & Gaskell, 2002; Männel & Friederici, 2009). In German adults and 6 year-old children this component was observed, even in the absence of a pause. CPS was also observed in 3 year-olds, but not in 21 month-olds. However, in 3 year-old children, the CPS component disappeared when the pause cue was missing from the signal (Männel & Friederici, 2011; Männel, Schipke, & Friederici, 2013). Aiming to understand the relative weight of different IP boundary cues, Männel & Friederici (2016) looked at brain responses in 3 year-old children, this time neutralizing the IP boundary pitch change cue, and keeping the pause and preboundary lengthening. A CPS response was found in the absence of pitch change. According to the authors, these results suggest a developmental trend in prosodic processing, where cues are weighted differently at different stages. This variation in the relative weight of different IP boundary cues has also been shown to depend on language-particular properties, with English children giving more weight to the pitch cue than German children (Seidl & Cristià, 2008; Féry, Hörnig, & Pahaut, 2011).

Despite the attested early ability to use phrasal prosody to constrain lexical access, demonstrated by English, French and Korean young children, and the presence of the CPS component at least as early as age three (for German children), a series of studies addressing young children's ability to use phrasal prosody to interpret syntactically ambiguous sentences has failed to show the expected effect of prosody on syntactic ambiguity resolution. Choi & Mazuka (2003) tested globally ambiguous utterances where the location of a prosodic break, with the exact same cues as those that characterized the examples in (3-4) above, determines a subject (3) versus an object interpretation (4).

Korean-learning 4-year-olds, and even 5-6 year-olds, were not able to successfully disambiguate the sentences, relying on phrasal prosody.

(3) **Kirin**] **Kwaja** mEgEyo ((A) giraffe eats cookies.)

(4) **Kirin Kwaja**] mEgEyo ((Somenone) eats giraffe-shaped cookie.)

Similarly, studies with English-learning preschoolers found little or no effect of prosody on their interpretation of ambiguous sentences (Snedeker & Trueswell, 2001; Vogel & Raimy, 2002; see also Chapter 3 of this thesis). Of particular interest to the current study, is the finding by Vogel & Raimy (2002) pointing to a late acquisition of the prosodic contrast between compound words and corresponding phrases (e.g., the compound 'hot dog' versus the phrase 'hot dog'), with younger children (between 5 and 6 years of age), demonstrating a preference for compounds regardless of prosody.

The study by Snedeker and Yuang (2008) and the recent work by De Carvalho and colleagues (2015, 2016) constitute exceptions to this picture. Snedeker and Yuang (2008) showed that English-learning 5-year-olds are able to use prosody to guide their interpretation of globally ambiguous utterances. Using locally ambiguous sentences, De Carvalho et al. (2016a) demonstrated that French-learning infants as young as 3.5 years old are able to use prosody to constrain their syntactic analysis. Similar results were found for English-learning 4 to 5 year-olds in De Carvalho et al. (2016b). In both studies, locally ambiguous sentences with noun/verb homophones were used (e.g., 'the baby flies] hide in the shadows' versus 'the baby] flies its kite'). The findings from these studies are reminiscent of Beach, Katz & Skowronski's (1996) results, which showed that both adults and 5 and 7 year-olds were able to use prosodic cues for phrasal interpretation. In the later study, the contrast was between 'pink and green] and white', and 'pink] and green and white'.

In all the studies reviewed so far, the phrasal prosody cues for disambiguation were described as local cues, namely the presence/absence/location of a phrasal boundary. Another type of prosodic cue that has been reported to affect ambiguity resolution are distal prosodic cues (Dilley, Mattys, & Vinke, 2010; Brown, Salverda, Dilley, & Tanenhaus, 2011; Breen, Dilley, McAuley, & Sanders, 2014). Distal prosody is described as prosodic cues or regularities prior to the locus of a particular prosodic event. Distal prosody is thus different from proximal prosody, i.e. the local cues. The interaction of distal prosody with proximal prosody was shown to have an effect in the time course of language processing (Dilley, Mattys, & Vinke, 2010). Similar patterns were also found in early and late ERP effects, suggesting that listeners are able to predict word boundaries based on a supportive prosodic context, rather than wait for all potential (local) segmentation cues (Breen, Dilley, McAuley, & Sanders, 2014). Therefore, the integration of prosodic information occurs in the course of a sentence unfolding, and crucially interpretation is also influenced by previous prosodic context (Dilley & McAuley, 2008; Brown, Salverda, Dilley, & Tanenhaus, 2011; Holzgrefe, Wellmann, Petrone, Truckenbrodt, Höhle & Wartenburger, 2013). As far as we know, the effects of distal prosody on ambiguity resolution in children's language processing have not yet been addressed.

Evidence for the presence of distal prosodic cues in EP has been described in the literature. In Prieto, D'Imperio, Elordieta, Frota, & Vigário (2006), a tendency is reported for speakers to produce long utterances with an initial higher peak. This phenomenon is interpreted as an instance of tonal preplanning in utterance production. Similarly, higher initial peaks are expected in sentences with a more complex prosodic structure, namely involving more prosodic breaks.

The experiments reported in this chapter aim to examine how phrasal prosody constrains lexical access and syntactic analysis in EP. The ability of EP-learning children to use prosodic boundary cues in ambiguity resolution is still unknown. We adopted De Carvalho, Dautriche, & Christophe (2016a) eyetracking experimental design to test 4 and 5 year old children, as well as adults as a control group. Sentences with global ambiguity were used to fully restrict disambiguation cues to prosodic properties. More specifically, the sentences used involved the contrast between a Prosodic Word boundary (PW) and IP boundary. This prosodic boundary contrast is a distinctive mark for word meaning, and syntactic structure. A PW boundary is present when the ambiguous target, for example 'guarda chuva' is a compound word, a noun, as in 'guarda-chuva' (umbrella), with the prosodic phrasing 'guarda]$_{PW}$ chuva'. An IP boundary marks the ambiguous target as two distinct nouns, 'guarda' (guard) and 'chuva' (rain), with the prosodic phrasing 'guarda]$_{IP}$ chuva'. As mentioned in chapters 2 and 3, both the PW and IP, are marked in the language by different prosodic cues, and described as domains of several phonetic and phonological phenomena. Given the clear and distinctive prosodic properties of PW and IP boundaries, we are interested to see whether young children, and adults, are able to use phrasal prosody to constrain sentence parsing.

The prosodic cues to IP boundaries in our stimuli are limited to pitch and duration. We opted for natural productions without a pause. This option was based on descriptions that show that pauses are optional, but not obligatory cues to IP boundaries in EP, unlike pitch and duration cues (Frota 2000, 2014).

In this study, eye-gaze data was tracked during on-line auditory processing. It is our goal not only to observe the processing of local prosodic cues, but also of potential distal prosodic cues. Although in the literature the term distal prosody is used to refer to a prosodic context prior to an ambiguous target, we considered both the prior and the subsequent prosodic context as potential sources of prosodic cues that may impact global ambiguity resolution. An off-line pointing task after sentence audition was also included, providing information about the participant´s final interpretation of the ambiguous sentence. In Experiment I, we examined adults' ability to use phrasal prosody in ambiguity resolution. Experiment II investigated whether 4 and 5 year-old children used phrasal prosody to guide sentence interpretation.

4.2 Experiment I: adult data

4.2.1 Method

- *Participants*

Twenty EP native speakers, all undergraduate students from the University of Lisbon (mean age 23, min. 19, max 31), participated in the experiment. One other participant was excluded, due to not performing the pointing task. All participants self-reported normal hearing and vision, or corrected vision, and no cognitive or other neurological deficits. To control for dialectal prosodic variation, we only tested native speakers of the Standard European Portuguese variety (SEP). All participants volunteered for the study.

- *Materials*

We first looked for compound words listed on adult lexica[5]. Since not all compound words served the purposes of our study, we focused on those that followed the criteria described below:

a) Compounds should contain internal items that in isolation could be interpreted as two nouns, as in the examples in (5):

(5) porta-chaves$_N$ > porta$_N$, chaves$_N$
key holder door, keys
(6) *corta-unhas$_N$ > corta$_V$, unhas$_N$
nail clipper (to) cut, nails

b) Compounds should allow a visual representation of both the compound word and their internal elements when used as independent words

5 Portal da Língua Portuguesa was used (http://www.portaldalinguaportuguesa.org/about.html?action=vop).

c) The visual representation of the compound and the elements internal to the compound when used as independent words should be sufficiently distinct not to admit ambiguous image interpretations. In (7), the visual representations of the words are not clearly distinct, as shown in Figure 4.2. Examples like those in (8) matched the selection criteria (Figure 4.3):

(7) couve-flor > couve, flor
a variety of cabbage..>..cabbage, flower

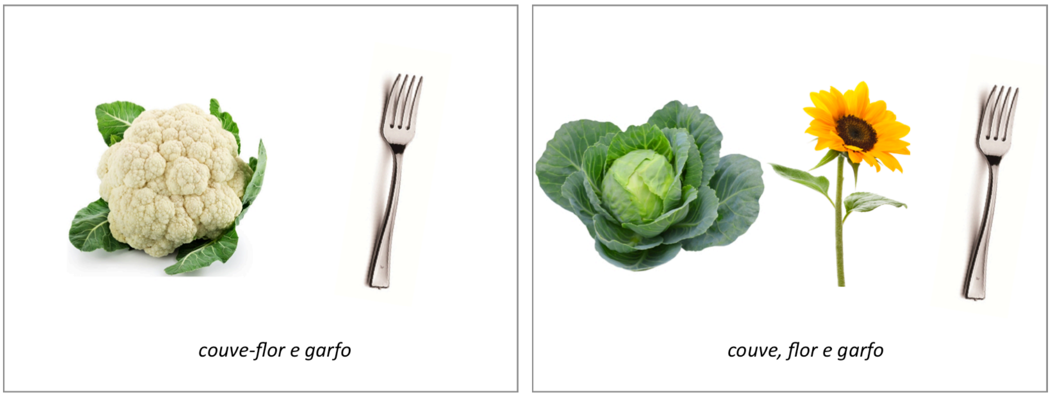

Figure 4.2: Visual representation of compound items and list items (6).

(8) porco-espinho > porco, espinho
hedgehog > pig, thorn

Figure 4.3: Visual representation of compound (7).

c) Both the compounds and their internal members when used as independent words should be words known by the children.

As an indication that the selected words as well as the words that would be used to compose the sentences were part of the vocabulary of 4 and 5 year-olds, we looked at children's lexical databases available for EP. We used the PLEX5 database (Frota, Correia, Severino, Cruz, Vigário, & Cortês, 2012) and the Childes Portuguese database[6]. From the Childes database, we have used Santos, Freitas and CCF, which matched PLEX5 data and included a lexicon of children under 3 years of age[7]. Alegre, Alegrex and Florianopolis, also in the Childes Portuguese database, are data from Brazilian Portuguese speaking children and therefore were not considered for our purposes. Batoreo's database was also not used because, as it contains a lexicon from older children (from 5 to 10 years of age), and contains a more limited lexicon since it results from elicited narratives of two short stories. The databases used here result from spontaneous speech data.

The compounds selected for our study (see Appendix I) were not present in the databases inspected, with the exception of 'fita-cola' (tape) and 'guarda-chuva' (umbrella). Nevertheless, it is known that lexical databases based on production are necessarily limited and do not exactly mirror children's productive and receptive vocabulary. Some of them are included in the adapted version of the prosodic test - Profiling Elements of Prosody in Speech-Communication (PEPS-C) - to EP (Filipe, 2014). However, the results from this study do not allow us to check children's results. Thus, because the selected words matched the established criteria from all other perspectives, and because they were thought to most probably be known by the children, we further conducted a picture naming task involving all of the target words that we wanted to use. A group of 10 children between 4 and 5 years of age did the task. All children named the pictures correctly, using the expected words. This filled the gap for the words absent from the databases consulted. This procedure allowed us not only to check for children's lexicon, but also to validate the pictures to be used in our experiment. Overall, we were able to include seven compound words (see Appendix I). For each word, we built two globally ambiguous sentences, one containing the compound word as target and the other containing the independent words that formally correspond to the internal members of compounds, as illustrated in (9-10).

(9) O Tito já disse **guarda** $]_{pw}$ **chuva** e pato
Tito already said umbrella and duck

(10) O Tito já disse **guarda** $]_{ip}$ **chuva** e pato
Tito already said guard, rain, and duck

[6] http://childes.talkbank.org/data/Romance/Portuguese/

[7] Santos, Freitas e CCF databases include productions from 0;10.2 to 4;10.7 years old.

The syntactic structure of the sentences followed the canonical word order in European Portuguese (Subject Verb Object), also present in children's speech at the target age. As for the controls, 10 unambiguous sentences were created with the same structure, and using words that were part of the children's lexicon (See appendix I.)

Sentences from each pair (as in 9-10 above) were assigned to two blocks (block 1 and block 2), each block containing sentences for both PW and IP boundary levels. To control for picture side presentation, picture counterbalance was achieved by having 2 versions for each block, in a total of 4 experimental blocks (block 1A, block 1B, block 2A, block 2B). In total, each experimental block contained 7 test sentences and 5 control sentences, totalling 12 trials per block.

A trained female speaker recorded the sentences (44100hz, 16 bit, mono) at the Lisbon Baby Lab facilities. Acoustic analyses were performed for tonal events, pitch range[8], pitch reset[9], and syllable duration, to identify the exact acoustic cues for the prosodic boundary contrasts. Table 4.1 shows the local prosodic cues. The expected duration, pitch range and pitch reset differences were found, with the IP boundary condition showing larger values for all three measures, as a result of pre-boundary lengthening, the presence of a boundary tone (H%), and the subsequent longer sentence duration.

Table 4.1: Acoustic analyses for pitch and duration at the ambiguous target: Local prosodic cues.

Local Prosodic Cues								
Boundary	sentence length (ms)	syllable duration_before boundary (ms)		syllabe duration_after boundary (ms)	pitch range (hz)			pitch reset (hz)
		S1	S2	S3	S1	S2	S3	
PW								
average	4415	205,1	122,5	242	-21,27	-19,48	-31,51	-29,93
standard deviation	142,7	43,1	25,3	36,9	10,38	17,30	34,88	16,59
IP								
average	4948	372	236	211	-49,79	67,00	-46,91	-100,98
standard deviation	192,8	89,1	33,8	42,5	21,59	40,34	58,35	35,93
average difference	4681,3	288,8	179,1	226,9	-35,5	23,8	-39,2	-65,5

Acoustic analyses to inspect for distal prosodic cues were also performed for pitch and duration, before and after the ambiguous target. As noted in Table 4.2, there is prosodic evidence contrasting the two conditions that spreads over the whole sentence. Prior to the target, the very initial peak of the sentence is higher in the IP condition, and the duration and pitch range values of the pre-target syllable are also longer. After the target, the very

[8] pitch range: *f*0 difference between the value of highest and lowest pitch point of the target syllable..
[9] pitch reset: difference between the stable point of the following vowel and the value of target highest pitch point.

last F0 peak in the sentence is higher in the IP condition, and the pitch range in the last word is wider, with a larger pitch fall. Quite notably, we find several distal cues, the most remarkable of which are found at the very onset of the sentence (the height of the first peak) and at the very end of the sentence (the height of the last peak and the final pitch range). Two illustrative sentences are provided in Figure 4.4.

Table 4.2: Acoustic analyses for pitch and duration before and after the ambiguous target: Distal prosodic cues.

	Distal Prosodic Cues (before ambiguous target)			Distal Prosodic Cues (after ambiguous target)		
Boundary	pre-target word pitch peak (hz)	pre-target word stress syllable duration (ms)	pre-target word stress syllable range (hz)	last word pitch peak (hz)	last word stress syllable duration (ms)	last word stress syllable range (hz)
PW						
average	307,7	329	-48,9	239,7	377	-59,8
standard deviation	13,2	78,5	15,0	26,9	99,4	11,9
IP						
average	343,5	435	68	283,2	345	-106
standard deviation	37,4	68,4	35,5	9,2	51,2	12,8
average difference	35,8	106	117,4	43,6	31,6	46,0

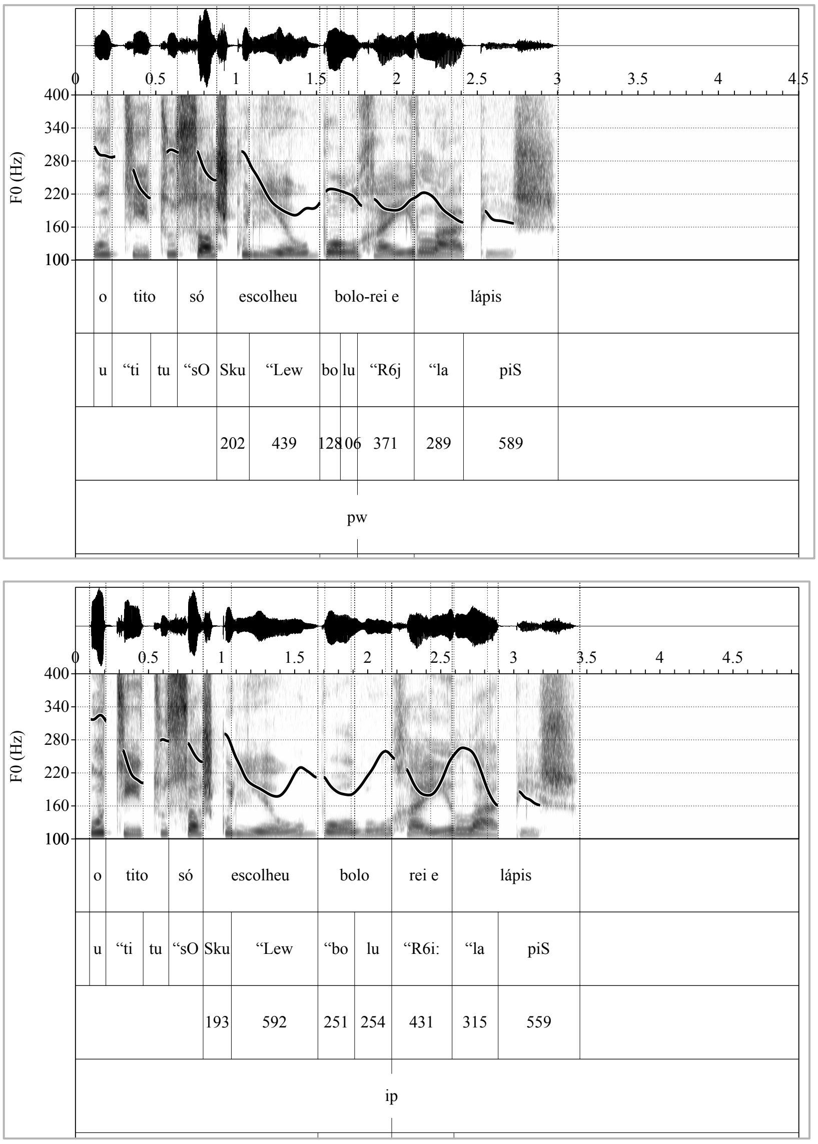

Figure 4.4: Pitch contour and syllable duration of the sentences O Tito só escolheu bolo-rei/bolo, rei e lápis. The two phrases are distinguished in the target word, with a clear effect of the prosodic boundary phrasing.

Since we were testing globally ambiguous sentences, differently from De Carvalho et al. (2016), who tested locally ambiguous sentences, sound files were edited to have a 1500ms silence after sentence offset. The idea was to ensure a time span for sentence processing after the last word. Trials were pseudo-randomized to avoid presentation of more than two stimuli with the same boundary condition in a row.

For each pair of ambiguous sentences, two images were created, one representing the compound word meaning and the other one the list meaning. A total of twenty-eight images were created, with similar sizes and complexity (see Appendix 2). The images were validated by children using a picture naming task, as indicated above.

- *Procedure*

Participants were asked to validate an experiment designed for children based on degree of difficulty and motivation. No other instructions were given besides these, that were presented at the start of the experiment. They were comfortably seated 70 cm from a 1680x1050 monitor equipped with a SMI remote eyetracking system and wore headphones to listen to stimuli.

The experimental design was inspired by De Carvalho et al. (2016a) experiment 2, an intermodal preferential looking task. Each trial included 3 phases - baseline, test and pointing - with a total of 9 events, as shown in Figure 4.5).

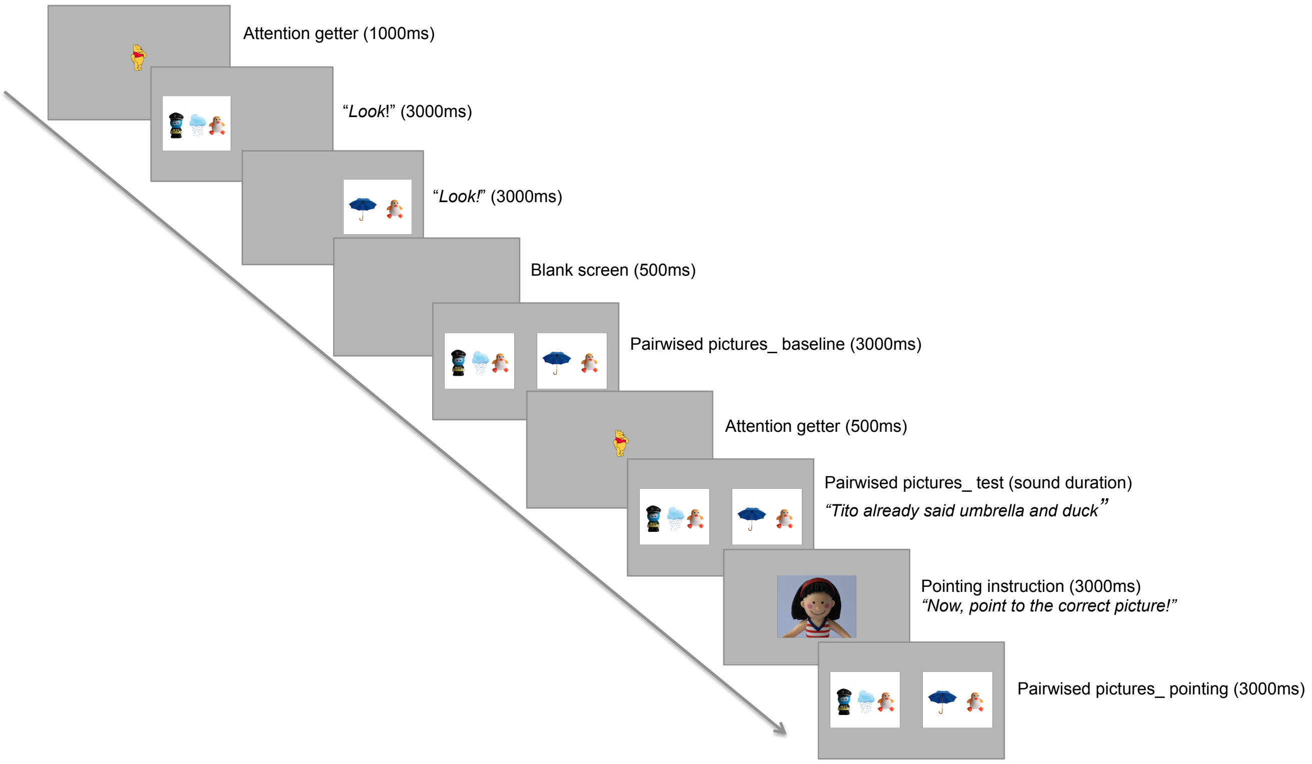

Figure 4.5: Events' sequence during trial presentation

Each participant was assigned to one of the four experimental blocks. Blocks started with a doll explaining the game to the participant, and two training trials with feedback given. Experimental trials began with a 1000ms fixation point in the middle of the screen, followed by picture presentation: first, each picture was presented individually with audio reinforcement (*Olha!*), and, after a 500ms blank screen, both pictures were presented side-by-side, for 3000ms. This last event is the baseline for our testing, since pictures are presented with no sound association. Another event with a 1000ms fixation point brings participant's attention to the middle of the screen, and a test event started with a sentence playing as paired pictures appeared again. During the next event, a doll asks for the participant to point to the picture he/she considered being the one that matched the meaning of the sentence heard. Paired pictures appear for the third time for 3000ms, to allow the participant to make a pointing decision. Participants completed the experiment when all trials were finished, taking average 5.38 minutes.

4.2.2 Data processing

Data processing followed the same general procedure as for the adult experiment reported in chapter 3, with the following difference.

Since in the current experiment the sentence started to play as soon as the paired pictures reappeared on screen (event 7 of each test trial), gaze data was extracted considering three temporal analyses. In temporal analysis 1, we adopted a time frame similar to De Carvalho, Dautriche, & Christophe (2016a), where the time course of eye movements was considered from -700ms before the onset of the ambiguous word until 1500ms after the end of the ambiguous word, and participants were able to answer before the end time. Since we tested prosodic boundary cues between a compound word/two words, we conducted the analysis from the first ambiguous word onset (e.g. 'guarda' in the case of 'guarda chuva') until 1500ms after the target prosodic boundary. This window of analysis is intended to capture the on-line interpretation of the phrasal prosody cues available as proximal prosody. In temporal analysis 2, and because we used globally ambiguous sentences for testing, we expanded temporal analysis from the first ambiguous word onset until the end of the trial. With this, we wanted to capture eventual late effects in sentence ambiguity processing, namely distal prosody effects near the end of the sentence, which could be only processed after sentence offset. In temporal analysis 3, we considered all trial duration for global sentence processing, taking into consideration eventual effects of distal prosody at the very beginning of the sentence that could be only captured in early prosodic processing.

4.2.3 Data analysis

As for the experiment reported in chapter 3, we first conducted pointing data coding for control trial errors, since we defined control trial errors as exclusion criteria. No adult participant was excluded. As described above, experiment I was composed of two versions for each of the two blocks, with a total of 4 experimental blocks: block 1A, block 1B, block 2A, and block 2B. The difference between block versions (A and B) was the picture counterbalance by side (left/right, right/left). Based on pointing results, we conducted an Independent t-test to compare picture side effects, looking at statistical differences between the two versions of each block. Pointing direction was normally distributed for both groups and that there was homogeneity of variance as assessed by Levene's Test for Equality of Variances. We found that there were no significant differences in the scores for none of the A/B blocks: for block 1A (M=.31, SD=.471) and block 1B (M=.43, SD=.502); t(68)=-.982, p = 0.330; for block 2A (M=.46, SD=.505) and block 2B (M=.49, SD=.507); t(68)=-.236, p = 0.814. These results indicate that participants behaved similarly in both versions of each block, regardless of picture position. Based on these results, we excluded picture counterbalance as a variable for further analysis and grouped block versions together: blocks 1A and 1B > block version 1; blocks 2A and 2B > block version 2.

For gaze data analysis, a repeated measure ANOVA was conducted, with trial phase (baseline *vs* test) and boundary condition (Low=PW *vs* High=IP) as within-subject factors, and experimental block (version 1 *vs* version 2) as a between-subject factor. A Paired-sample t-test was conducted to compare the proportion of looks in trial phase and boundary level conditions (Baseline Low *vs* Baseline High; Test Low *vs* Test High; Baseline Low *vs* Test Low; Baseline High *vs* Test High).

For pointing data, boundary condition was a within-subject factor (Low *vs* High) and experimental block a between-subject factor (version 1 *vs* version 2).

4.2.4 Results

In all three temporal analyses, the main effects of Boundary Condition and Block were not significant (p>.5). In what follows, we report only significant differences in the results.

- *Eye Gaze Results: Temporal analysis 1 (target word onset until 1500ms after target prosodic boundary)*

In temporal analysis 1, which captures the on-line interpretation of the phrasal prosody cues available as proximal prosody, a main effect of Trial Phase was found ($F(1;18)=4.490$; $p = 0.048$; $\eta^2 = 0.200$), together with a significant interaction Trial Phase*Boundary Condition ($F\,(1;18)=12.952$; $p = 0.002$; $\eta^2 = 0.418$). The main effect of Phase indicates that participants' gaze behavior differs between the baseline and the test phases, showing an effect of listening to auditory stimuli. The significant interaction reveals that the boundary condition (PW or IP) affects gaze behavior differently between the two phases, as shown in Figure 4.6. Paired-sample t-tests showed that the observed effects emerged from the significant difference in proportion of looks between the baseline and the test phase in the High (IP) condition (baseline: M=.557, SD=.070; test: M=.635, SD=.133; t(19)=-2.571, p = 0.019), and also between test phase in the Low (PW) condition and the test phase in the High condition (Low test: M=.494, SD=.184; High test: M=.635, SD=.133, t(19)=-3.596, p = 0.002). Thus, the results indicate that participants were sensitive to the prosodic cues that signal the high boundary (IP), and that are located close to the ambiguous word and target boundary, and interpret the sentences accordingly. This shows that the effects of phrasal prosody, namely the presence of an IP boundary, emerge early in the process of sentence unfolding. Despite the absence of the pause cue, pitch and durational cues were enough to constrain adults' interpretation of globally ambiguous sentences.

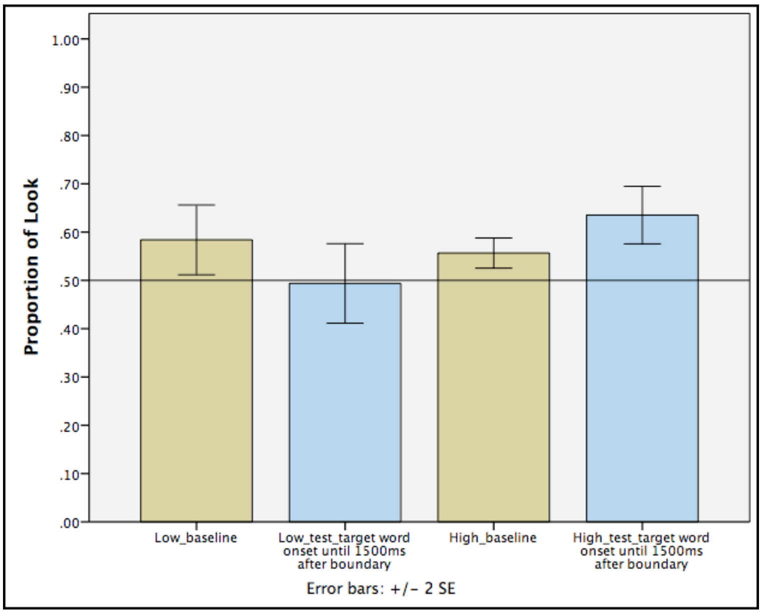

Figure 4.6: Adults' proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 1 (windowed trial duration from target word onset until 1500ms after target prosodic boundary)

- *Eye Gaze Results: Temporal analysis 2 (target word onset until end of trial)*

In temporal analysis 2, which captures eventual late effects in sentence ambiguity processing due to distal prosody cues near the end of the sentence, a significant main effect of Trial Phase was found ($F(1;18)= 8.631$; p = 0.009; $\eta^2 = 0.324$), showing a clear difference in adults eye gaze between baseline (M=.507) and test phases (M=.587). Like for temporal analysis 1, a statistically significant interaction of Trial Phase*Boundary Condition was also found ($F(1;18)=17.176$; p = 0.001; $\eta^2 = 0.488$). Paired-sample t-tests showed a significant difference in proportion of looks for Low baseline and Low test (baseline: M=.584, SD=.162; test: M=.430, SD=.174; t(19)=3.239, p = 0.004), and also for Low test and High test (Low: M=.430, SD=.174; High: M=.618, SD=.131, t(19)=-4.396, p = 0.000). As depicted in Figure 4.7, participants were now mainly sensitive to the prosodic cues that signal the low (PW) boundary. These results show that distal prosody cues located after the target boundary and near to the end of the sentence also play a role in sentence parsing, in particular signaling the presence of a PW boundary (and the absence of an IP boundary), which triggers the compound word interpretation.

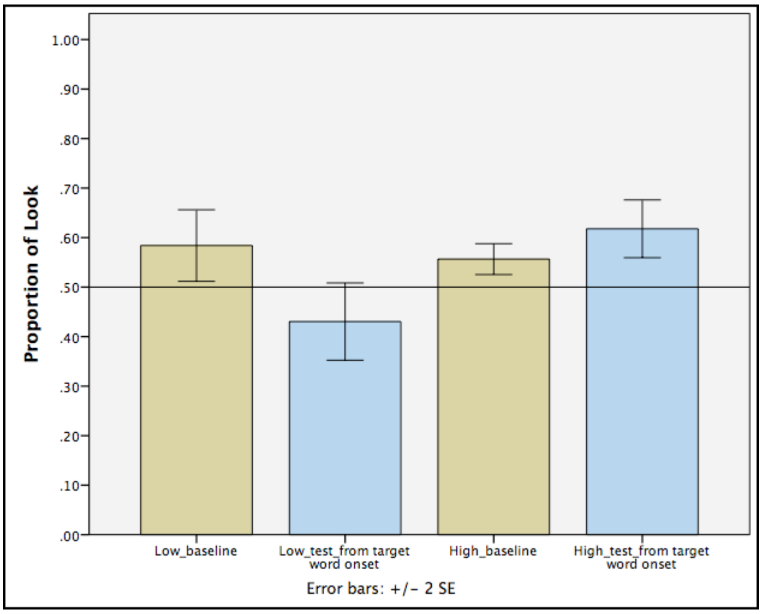

Figure 4.7: Adults' proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 2 (Windowed trial duration from target word onset until end of trial).

- *Eye Gaze Results: Temporal analysis 3 (all trial duration)*

In temporal analysis 3, which included the whole trial, eventual effects of distal prosody at the very beginning of the sentence that could be only captured in early prosodic processing were also considered. Eye gaze data showed a statistically significant main effect of Trial Phase ($F(1;18)= 4.990$; $p = 0.038$; $\eta^2 = 0.217$), with the net dwell time during baseline phase differing from that of test phase, where images were presented together with auditory stimuli. Again, a significant interaction of Trial Phase*Boundary Condition was found ($F(1;18)=18.512$; $p = 0.000$; $\eta^2 = 0.507$). This interaction was statistically stronger than that observed in the previous temporal analysis. Paired-sample t-tests showed significant differences in proportion of looks for Low baseline and Low test (baseline: M=.584, SD=.162; test: M=.442, SD=.174; t(19)=3.333, p = 0.003), and also for Low test and High test (Low: M=.442, SD=.174; High: M=.602, SD=.120;, t(19)=-3.872, p = 0.001; see also Figure 4.8).

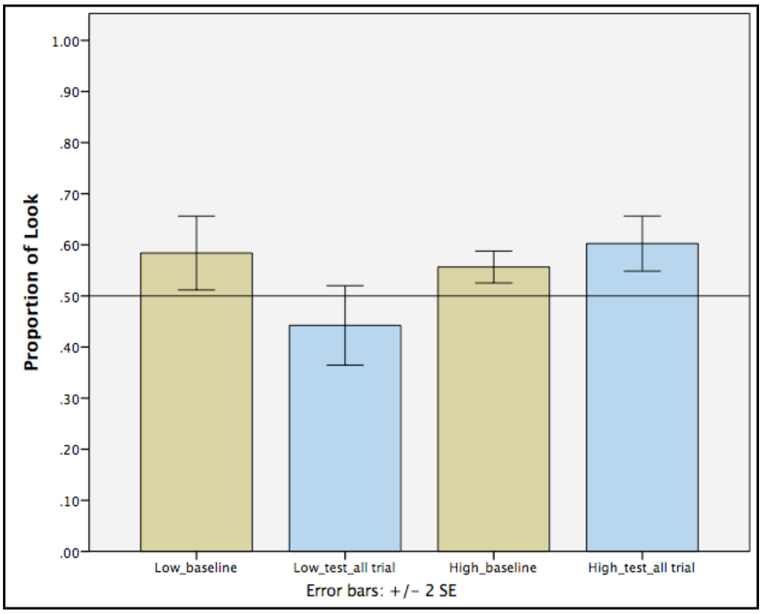

Figure 4.8: Adults' proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 3 (all trial).

For the longest time window (all trial), the significant effects were similar to those found for the temporal analysis 2 (target word until end of trial), suggesting that possible effects of distal prosodic cues present at the beginning of the sentence add to the signaling of the PW boundary (and thus absence of an IP boundary), which favors the compound word interpretation.

- *Pointing Results*

The off-line pointing task, performed 4500ms after sentence offset, yielded the following results. The ANOVA revealed a significant main effect of Boundary Condition ($F(1,18)=115.5$, $p = 0.000$; $\eta^2 = .865$). No effect of Block ($F(1,18)=.014$, $p = 0.907$, $\eta^2 = .001$), or interaction Boundary Condition*Block ($F(1,18)=2.358$, $p = 0.142$ $\eta^2 = .116$) was observed. Figure 4.9 shows pointing direction to boundary condition: when asked to point to the picture that participants consider represented sentence meaning, adult participants clearly disambiguate between the compound word reading and the list reading, solely based on the acoustic cues of phrasal prosody. As previously found in reports for production, the presence of a PW between the two ambiguous words indicated a compound word, whereas an IP boundary in the same position indicated independent words in a list phrasing structure.

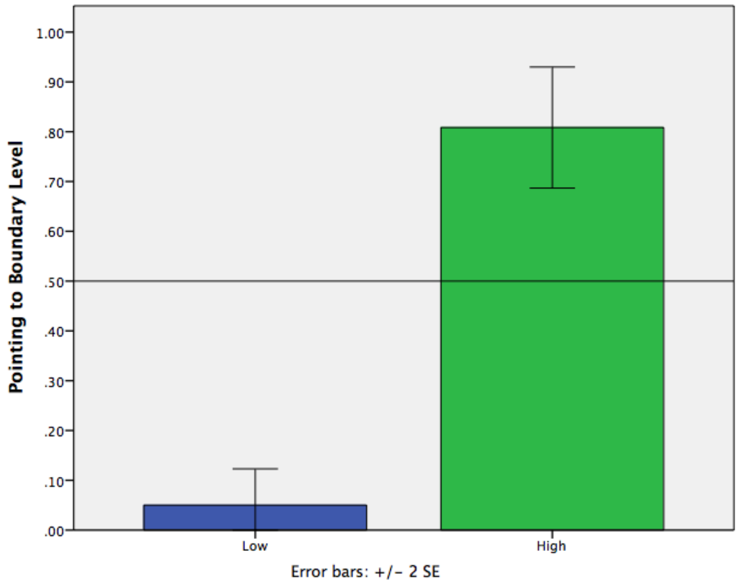

Figure 4.9: Adults' pointing direction to the image reflecting the list (high boundary) interpretation, by boundary condition (Low for PW; High for IP).

4.2.5 Discussion

In general, the eye gaze results from the looking task showed that phrasal prosody had an effect on the processing of globally ambiguous sentences by adult participants. Participants assigned different structures and interpretations depending on the type of prosodic boundary, with the PW boundary ('guarda]$_{pw}$ chuva') triggering the compound word interpretation (umbrella) and the IP boundary ('guarda]$_{ip}$ chuva') the phrasal list interpretation (guard, rain). However, some interesting differences were found between the time windows considered for analysis. In the time window that looked at the effect of local prosodic cues, the difference between baseline and test events was only not strongly significant, but crucially the boundary condition (PW or IP) affected gaze behavior differently in the two trial phases showing the impact of auditory stimuli. Furthermore, the results revealed that local prosodic cues are mainly effective in signaling the presence of the IP boundary. In the time windows that also included effects of distal prosody, the difference between baseline and test events was now significant, revealing stronger effects of auditory stimuli. Differently from local prosody, distal prosody, whether prior or subsequent to the ambiguous target, was particularly effective in signaling the presence of the PW boundary. For all time windows, eye gaze clearly indicated disambiguation between the PW and IP boundary conditions in the test phase. The pointing results mirror the eye gaze results, with participants pointing to the image representing the compound word meaning when listening to the sentence with the PW boundary and to the image representing the list meaning when listening to the sentence with the IP boundary.

Having established that adults were able to successfully use phrasal prosody in ambiguity resolution, we asked whether young children's interpretation of sentences ambiguous between compound word and phrasal list readings was also influenced by phrasal prosody in similar ways.

4.3 Experiment II: children data

The ability of EP-learning children to use prosodic boundary cues in ambiguity resolution is still unknown. To investigate this ability we conducted an experiment using the same materials and method used in Experiment I to test 4 and 5 year old children. We were interested to see whether young children, similarly to adults, are able to use phrasal prosody to constrain sentence parsing, and whether any developmental trends emerged between 4 and 5 years of age. The age range tested was chosen on the basis of previous findings for other languages that suggested a better performance of 5-year-olds relative to younger children (Choi & Mazuka, 2003; Snedeker & Yuang, 2008; De Carvalho et al., 2016a).

4.3.1 Method

- *Participants*

Children's parents gave written consent forms for participation and reported no cognitive or neurological disorders based on regular medical evaluation[10]. We have tested 52 monolingual native EP speakers, split into two age groups with 26 children each: the 4-year-old group (15 boys, mean age 4 years, 4 months and 16 days, range 3 years, 9 months and 18 days – 4 years, 10 months and 18 days), and the 5-year-old group (14 boys, mean age 5 years, 4 months and 21 days, range 4 years, 11 months and 11 days – 5 years, 8 months and 15 days). An additional five children were excluded: for being bilingual (3), for fussiness (1), and because of calibration failure (1). Children were rewarded with a participation certificate.

[10] In Portugal, medical doctors from the national healthcare system regularly follow children at least until age 5. In most schools, medical evaluation is required for registration. The written consent form filled by parents is included in Appendix III.

- *Materials*

For this experiment, the materials were the same as those used in Experiment I.

- *Procedure*

All children participated individually in a quiet room. The testing procedure was the same as in Experiment I, with a slight adaptation in the initial instructions given by the experimenter. To engage children in the task, we told them we were looking for the best performance based on how many points each participant would get. To gain points, they just needed to pay attention to the instructions given by the doll and to complete the whole game. Points counting would stop whenever they would look away from the screen. This procedure aimed to avoid gaze-tracking loss, in case the child would get distracted and look away from the screen. The experimenter gave feedback on the child's performance during training, to ensure that the task was understood. No further instructions were given.

4.3.2 Data processing

Data processing followed the same procedures as described for Experiment 1 (see section 4.2.2 above).

4.3.3 Data analysis

A repeated measures ANOVA was conducted for gaze data analysis, with Trial Phase (baseline *vs* test) and Boundary Condition (Low *vs* High) as within-subject factors, and experimental Block (version 1 *vs* version 2) and Age Group (4-year-old *vs* 5-year-old) as between-subject factors. Given that a statistically significant interaction between Boundary Condition*Age Group was found, we decided to analyze eye gaze data for each age group separately. In this second analysis, we followed the same model applied to adult data: a repeated measures ANOVA with Trial Phase (baseline *vs* test) and Boundary Condition (Low *vs* High) as within-subject factors, and experimental Block (version 1 *vs* version 2) as the between-subject factor.

Paired sample t-tests were conducted to compare the proportion of looks in phase and boundary level conditions (Baseline Low *vs* Baseline High; Test Low *vs* Test High; Baseline Low *vs* Test Low; Baseline High *vs* Test High).

For the pointing data, a statistically significant interaction Boundary Level*Age Group was also found, which lead us to analyze age groups separately. As for adult pointing data, a repeated measure ANOVA was conducted for each age group, with Boundary

Condition as the within-subject factor (Low *vs* High) and experimental block as the between-subject factor (version 1 *vs* version 2).

4.3.4 Results

- *Eye Gaze Results: Temporal analysis 1 (target word onset until 1500ms after target prosodic boundary)*

At this time window, both the first ANOVA with Age group as a factor and the second analysis by age group revealed no statistically significant main effects or interactions, suggesting that, unlike adults, children were not able to use phrasal prosody for ambiguity resolution in this shorter time window. As shown in Figure 4.10, children's eye gaze behavior was similar across conditions, and close to chance level, indicating that local prosodic cues are not used, or are not enough, to guide children's interpretation.

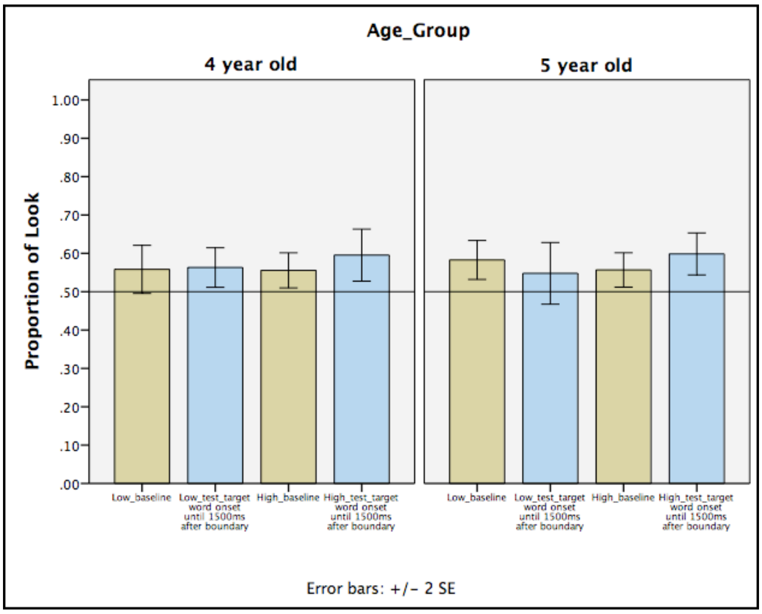

Figure 4.10: Children's proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 1 (time window from first ambiguous word onset until 1500ms after target prosodic boundary).

- *Eye Gaze Results: Temporal analysis 2 (target word onset until end of trial)*

The ANOVA with Age Group as a within-subject factor showed a significant effect of Trial Phase*Boundary Condition ($F(1;50)=4.099$; $p = 0.048$; $\eta 2 = .076$), pointing to age group differences in how the boundary condition (PW or IP) affected gaze behavior in the two phases. When each age group was analyzed separately, only the 5-year-old's data revealed a significant interaction of Trial Phase*Boundary Condition ($F(1;24)=6.187$; $p = 0.020$; η2 =.205). No other main effects or interactions were observed.

Paired-sample t-tests for 5-year-olds revealed significant differences between Low baseline and Low test (Baseline: M=.583, SD=.130; Test: M=.474, SD=.180; $t(25)=2.245$, $p = 0.034$), and Low test and High test (Low: M=.474, SD=.180; High: M=.594, SD=.142; $t(25)=-2.555$, $p = 0.017$), similar to the adult pattern (Figure 4.11).

These results indicate the ability of 5-year-old children to perceive phrasal prosody cues to solve global ambiguity, when distal prosodic cues are also available. However, this ability is not yet present in 4-year-olds.

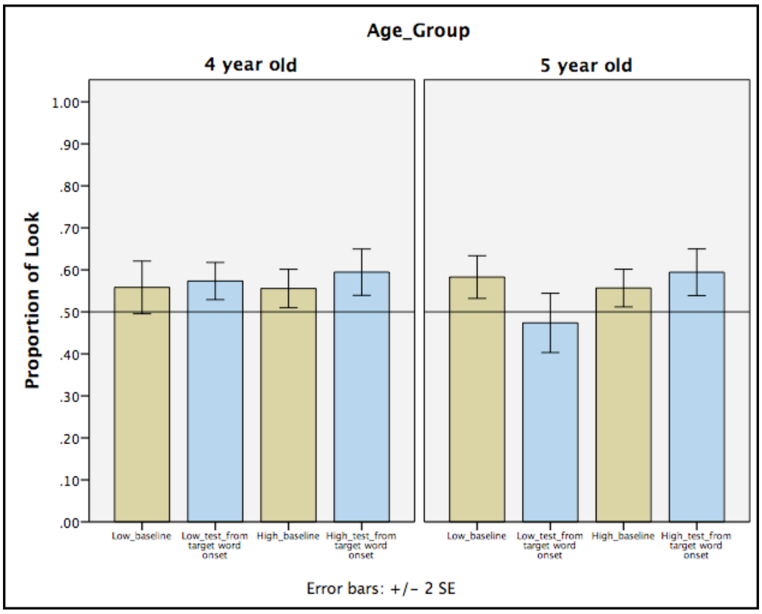

Figure 4.11: Children's proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 2, (Windowed trial duration from target word onset until end of trial).

- *Eye Gaze Results: Temporal analysis 3 (all trial duration)*

Results from the ANOVA with Age Group as a within subject factor revealed a significant interaction of Boundary Condition*Age Group ($F(1;50)=5.901$; p 0.019; η2 = 0.106), and Trial Phase*Boundary Condition (F (1;50)=5.092; $p = 0.028$; η2 = 0.092), showing, as in temporal analysis 2, age group differences in how the boundary condition (PW or IP) affected gaze behavior in the two phases. When the two age groups were analyzed separately, significant effects were found only for 5-year-olds. A borderline main effect of Trial Phase emerged for the first time in children's data (F (1;24)=3.949; p 0.058; η2 = .141), indicating that children's gaze behavior differed between the baseline and the test phases showing an effect of listening to the auditory stimuli. Furthermore, a stronger interaction Trial Phase*Boundary Condition was observed (*F* (1;24)=7.217; p .013; η2 = .231), when compared to the previous time window.

Paired-sample t-tests for 5-year-olds revealed significant differences for Low baseline and Low test (Baseline: M=.583, SD=.130); Test: M=.472, SD=.148; t(25)=2.667, p = 0.013), and Low test and High test (Mow: M=.472, SD=.148; High: M=.576, SD=.114; t(25)=-2.882, p = 0.008). Again, these results, shown in Figure 4.12, mirror the adult pattern.

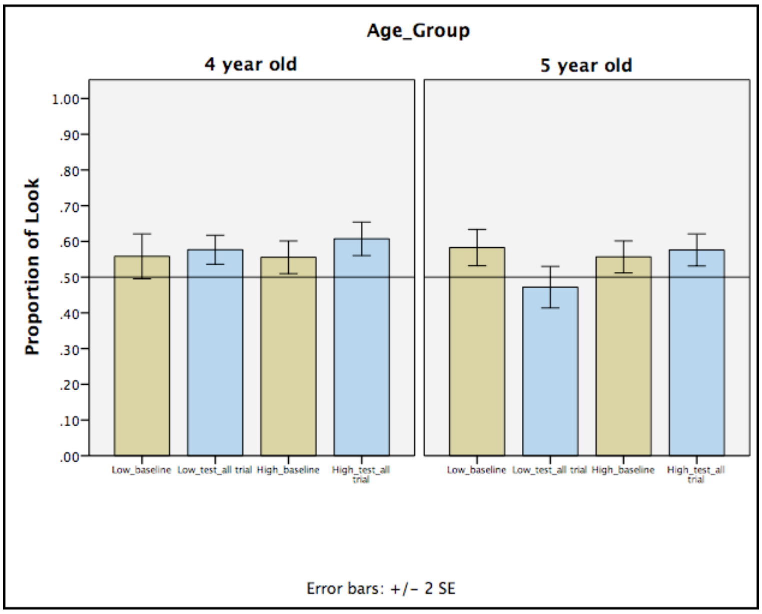

Figure 4.12: Children's proportion of looks to the image reflecting the list (high boundary) interpretation for temporal analysis 3 (all trial),

These results offer further confirmation of the ability of 5-year-old children to perceive phrasal prosody cues to solve global ambiguity, when distal prosodic cues are also available. In fact, this ability is strengthened when distal prosody found both preceeding and succeeding the ambiguous target is processed by the children. Again, this ability is not yet shown by 4-year-olds.

- *Pointing Results*

The pointing responses were analyzed separately by age group. The 4-year-olds pointing data followed the pattern observed in the gaze data, with no significant main effects or interactions. By contrast, 5-year-olds pointing data confirm the results shown by gaze data, revealing a significant main effect of Boundary Condition (*F* (1;24)=19.765; p.000; η2 = .452). No main effect of Block or interaction Boundary Condition*Block was observed.

As can be seen in Figure 4.13, 5-year-olds, but not 4-year-olds, clearly disambiguate between the compound word reading and the list reading, solely based on the acoustic cues of phrasal prosody, as adults do. This result is a further demonstration that the older children have the ability to use phrasal prosody to guide sentence interpretation in globally ambiguous sentences.

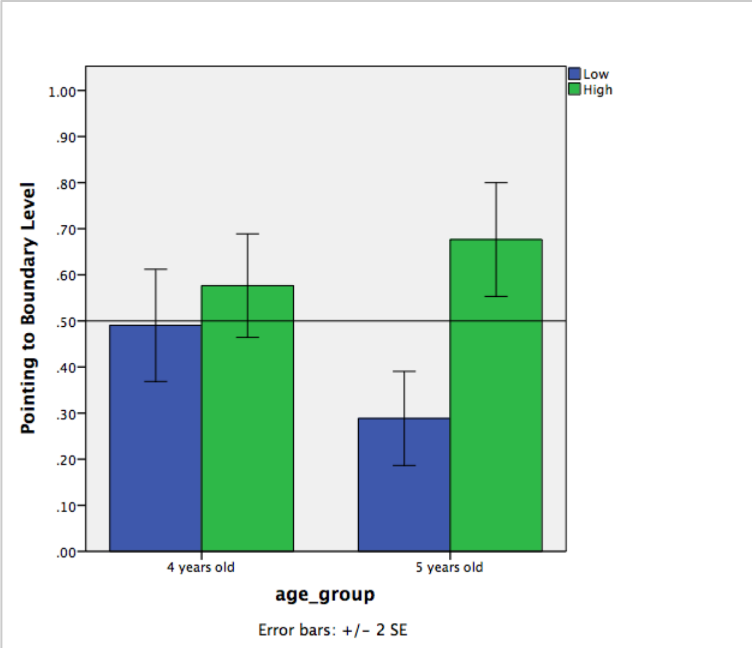

Figure 4.13: Children's pointing direction to the image reflecting the list (high boundary) interpretation, by boundary condition (Low for PW; High for IP), and age group..

4.3.5 Discussion

In Experiment II we tested whether young children, similarly to adults, were able to use phrasal prosody to constrain sentence parsing, and whether any developmental trends emerged between 4 and 5 years of age.

The main finding provided by the eye gaze results, together with the results from the pointing task, is that EP children are not able to resolve ambiguity on the basis of prosodic information before age 5. A developmental trend is shown in the results. At age 4, the eye gaze data showed no effects of phrasal prosody, regardless of the time window for analysis used, and the pointing data confirmed the inability of 4-year-olds to interpret globally ambiguous sentences. At age 5, effects of phrasal prosody on ambiguity resolution were already observed, but differed according to the time window of analysis, as shown in Table 4.3, suggesting that they were mediated by the kinds of prosodic cues available and their processing time. Unlike in De Carvalho et al. (2016a), no effects were found in the time window from the target word onset until 1500ms after the target prosodic boundary. Only in larger time windows, which favored the processing of both local and distal prosodic cues did phrasal prosody effects emerge. Stronger effects were found when all the prosodic cues available in the signal were processed by the children. Thus, the pointing data of 5-year-olds matches the adult pattern, even though children's performance is not as good as adult performance, with eye gaze data only approaching the adult-like pattern in the larger time window.

Table 4.3: Repeated measures ANOVA results for all statistically significant effects found in the three temporal analyses performed on eye gaze data, for adults and 5-year-olds.

Gaze Data Results				
		target word onset until 1500ms after tested prosodic boundary	target word onset until end of trial	all trial duration
Phase	Adult	*F* (1;18) 4.490; p .048; η^2 = 0.200	*F* (1;18) 8.631; p .009; η^2 = .324	*F* (1;18) 4.990; p .038; η^2 = 0.217
	5 year old	*F* (1;24) .231; p .635; η^2 = .010	*F* (1;24) 3.847; p .062; η^2 = .138	*F* (1;24) 3.949; p .058; η^2 = 0.141
Phase*Boundary Level	Adult	*F* (1;18) 12.952; p .002; η^2 = .418	*F* (1;18) 17.176; p .001; η^2 = .488	*F* (1;18) 18.512; p .000; η^2 = 0.507
	5 year old	*F* (1;18) 1.660; p .210; η^2 = .065	*F* (1;24) 6.187; p .020; η^2 = .205	*F* (1;24) 7.217; p .013; η^2 = 0.231

This suggests that children's ability to use phrasal prosody to guide sentence interpretation is still developing beyond age 5. Nevertheless, the current findings are in line with previous reports for other languages (e.g., Choi & Mazuka, 2003; Snedeker & Yuang, 2008; De Carvalho et al., 2016a) that have shown better performance of 5-year-olds relative to younger children.

4.4 General Discussion

The experiments reported in this chapter provide support for the role of phrasal prosody in sentence parsing. It was shown that in globally ambiguous sentences where the differences in phrasal prosody are directly triggered by the syntax-prosody interface, and are thus part of the default prosody of the sentence (Vigário, 2003, 2010), as in the case of the contrast between a sequence with a compound word ('guarda-chuva e pato,' *umbrella and duck*) and with a list of three nouns ('guarda, chuva e pato', *guard, rain and duck*), sentence interpretation is guided by prosodic cues. The prosodic cues were used both by adults and 5-year-old children to successfully determine the syntactic structure and meaning of the ambiguous sentences. This study is the first to report that EP-learning children are able to use phrasal prosody in ambiguity resolution.

The prosodic cues used in the current study contrast a PW boundary in the compound word reading with an IP boundary in the phrasal list reading. Given previous findings on the disambiguating role of IP boundaries, both in production tasks and language comprehension tasks (Vigário, 1997b; 1998; 2003b; Frota et al., 2010; Severino, 2011), it is expected that adult listeners would be able to use prosodic information for disambiguation. Furthermore, previous adult perception studies had reported clear results for sentences with prosodic contrasts between non-adjacent prosodic levels, as in the case of the PW and the IP (Frota, Vigário, & Severino, 2010; Severino, 2011). The distinction between the PW and IP boundaries, on the one hand, and the obligatory nature of the differences in phrasal prosody in the sentences used in the current study, on the other, constitute two fundamental differences between this study and the study reported in Chapter 3, where EP adults failed to use phrasal prosody to interpret globally ambiguous sentences.

The fact that EP-learning children were shown to be able to use phrasal prosody in ambiguity resolution at the age of 5 adds to previous studies about young children's abilities to use phrasal prosody in other languages, around the same age (Beach, Katz & Skowronski's, 1996; Snedeker & Yuang, 2008; De Carvalho, Dautriche, & Christophe, 2016a; De Carvalho, Lidz, Tieu, Bleam, & Christophe, 2016b). However, other studies have shown that 5-year-olds and even older children did not demonstrate an ability to use prosody for disambiguation (Snedeker & Trueswell, 2001; Choi & Mazuka, 2003; Vogel & Raimy, 2002). For example, Vogel & Raimy (2002) reported a late acquisition of the prosodic contrast between compound words and corresponding phrases (e.g., the compound 'hot dog' versus the phrase 'hot dog') in English, with children between 5 and 6 years of age demonstrating a preference for compounds regardless of prosody. Besides the possibility that in some of these studies the prosodic cues used were more of an optional than of an obligatory or default nature, as pointed out in De Carvalho et al. (2016a), differences in the types of cues present in the sentences together with language-particular use and or weight of prosodic cues may also explain the different findings. For example, in Vogel & Raimy (2002) only very local cues were available in the stimuli, with no supporting prosodic context, unlike in our study.

The result that distal prosodic cues mattered for European Portuguese 5-year-olds successful use of phrasal prosody in sentence disambiguation is, to our knowledge, a new finding. In fact, the stronger effects were found when all the prosodic cues available in the signal, proximal and distal, were processed by the children. Distal prosody has been reported to affect ambiguity resolution by adults (Dilley, Mattys, & Vinke, 2010; Brown, Salverda, Dilley, & Tanenhaus, 2011; Breen, Dilley, McAuley, & Sanders, 2014). However, the extent to which these cues are relevant for young children's successful and stable use of phrasal prosody remains largely unknown as most studies have focused on local cues, and examined effects in early time windows. It is possible that some of the failures in children's use of phrasal prosody previously reported in the literature could be due to not considering the potential contribution of distal cues.

A further important finding of the current study is that EP children were not able to resolve ambiguity on the basis of prosodic information before age 5. This finding is consistent with some previous work on other languages (e.g., Choi & Mazuka, 2003; Snedeker & Yuang, 2008), and seems at odds with other reports that children of 4 years of age or even younger use phrasal prosody to interpret syntactically ambiguous sentences (De Carvalho, Dautriche, & Christophe, 2016a, for French). Again, differences in the types of cues present in the sentences together with language-specific use/weight of prosodic cues may explain the different findings. For example, French prosody is phrased-based with accentual phrases being marked with pitch movements and duration cues at their edges (Jun & Fougeron, 2002; Jun, 2014), whereas EP is a language where only the head of the IP is systematically marked with pitch and duration cues (Frota 2000, 2014). The presence of regular and frequent prosodic cues in French versus irregular and sparse cues in EP makes French children more exposed, and arguably more sensitive, to prosodic cues, and thus able to exploit them for sentence parsing earlier in development.

Our results have shown a clear developmental trend in the use of phrasal prosody to guide sentence interpretation, from a general inability at age 4 to a still developing ability at age 5, when local cues are still not enough and the support of distal cues is necessary. We have investigated the ability to use prosody to constrain lexical and syntactic analysis. Therefore, in this study lexical, syntactic and prosodic knowledge of the language are combined. A different research question is whether phrasal prosody is exploited to chunk the speech signal into words by infants, in the absence of prior lexical knowledge. This is the topic of investigation of the study reported in the next chapter.

5 Beyond the edge factor: Phrasal prosody constrains word segmentation by 12-month-olds

5.1 Introduction

Infants' early sensitivity to prosody from very early on in development is well documented in the literature. As mentioned in chapter 2, several studies have demonstrated the role of prosodic information in infants' processing of the speech signal that they are exposed to. Experimental studies have shown that newborns use prosodic information to identify their native language and differentiate between languages, as well as to discriminate between words (Nazzi, Bertoncini & Mehler, 1998; (Nazzi, Floccia, & Bertoncini, 1998). During their first 6 months of life, learning mechanisms are developed, such as recognition memory, associative learning, statistical learning, social motivations and interactions, contributing to a growing assessment of the native language (Houston, 2011). Infants are thus exposed to various sorts of cues in the language input and are able to use several of these cues, such as rhythmic patterns based on stress (Kooijman, Hagoort, & Cutler, 2009; (Skoruppa, Pons, Bosch, Christophe, Cabrol, & Peperkamp, 2013), intonational properties (Frota, Butler, & Vigário, 2014), or phonemic contrast and statistical transition patterns (Saffran et al., 1996; Thiessen & Saffran, 2003), to crack into the speech signal and develop their native language. A fundamental step in that direction is word segmentation, i.e., the ability to identify individual words from speech, which is a challenge since speech is continuous. This ability plays a crucial role in language acquisition, namely in lexical development and the acquisition of syntax (Newman R. , Ratner, Jusczyk, Jusczyk, & Dow, 2006; Singh, Steven Reznick, & Xuehua, 2012).

Previous research has shown that infants use prosodic boundaries to constrain lexical access, early in their second year of life, as they do not compute chunks that span a prosodic boundary, such as '**pay**] **per**suades' as whole words like '**paper**' (Gout, Christophe & Morgan, 2004; Millotte, Margules, Dutat, Bernal & Christophe, 2010). However, the word segmentation literature has only very recently addressed the potential role of phrasal prosody in early word segmentation abilities, and to a very limited extent by contrasting words at utterance edges with words in utterance mid position (Seidl & Johnson, 2006; Johnson et al., 2014). The experiments reported in this chapter directly address the effect of phrasal prosody in early word segmentation beyond the edge factor, by examining prosodic boundaries in utterance internal position.

There is a large word segmentation literature showing that early segmentation abilities vary across languages. For monosyllabic words, English-learning infants show segmentation abilities at 7,5 months (Jusczyk & Aslin, 1995), German-learning infants exhibit this competence between 7 and 9 months (Höhle & Weissenborn, 2003), and in Spanish-Catalan infants this ability was reported to emerge at 6 months (Bosch, Figueras, Teixidó, & Ramon-Casas, 2013). However, in this work, the position of the word in the sentence, and presence/absence of pauses, was not taken into account. In a recent study using the same word segmentation paradigm originally used by Jusczyk & Aslin (1995), Floccia et al (2016) tested British-learning infants aged 8-10.5 months and reported their inability to segment words from continuous speech, except when tested with stimuli produced in infant-directed speech (IDS) style. It is well known that IDS exhibits a characteristic prosody, whose features have been reported to facilitate segmentation (Fernald & Mazzie, 1991).

Two studies have addressed the impact of prosodic phrasing in word segmentation by English-learning infants. Seidl & Johnson (2006) have shown that 7.5-month-olds segmented words at utterance edges easier than at utterance internal position. Johnson, Seidl, & Tyler (2014) reported successful segmentation as early as 6 months only when words were presented at the edges of utterances. In both studies, among the prosodic cues for utterance edge, there was a pause.

Segmentation abilities at utterance final and medial position were recently investigated with EP-learning infants (Butler, Severino, Vigário, & Frota, 2016). The monosyllabic target word forms were either presented at the final utterance edge, or in internal position which either corresponded to a simple word boundary or a phonological phrase boundary. The results showed that infants displayed segmentation abilities at the final edge as early as 6-month of age. In utterance internal position, infants failed to segment at 6-months, and segmentation abilities improved slightly at 9 months of age, but were still not as good as at the edge position. The EP study, while controlling better for prosodic structure, mirrored previous findings for English, thus providing cross-linguistic evidence for the so-called edge factor in early word segmentation. Again, in the EP study, there was a pause among the prosodic cues for the edge condition.

Position constraints were also observed in neonates' brain activity, when responding to violations of familiarized syllable sequences at utterance edges, but not in internal position. However, the insertion of a pause utterance-internally was revealed to be enough for neonates to perceive familiarized syllable sequence violations in utterance internal position (Ferry, et al., 2015). The event-brain potentials (ERP) literature has also examined the processing of prosodic boundaries in infants and young children. Importantly, the ERP component known to index an intonational phrase (IP) boundary, the Closure Positive Shift (CPS) component, was described to differ from obligatory ERP components that are simply elicited by a pause (Davis, Marslen-Wilson, & Gaskell, 2002; Männel & Friederici, 2009). It is thus possible that in the above described word segmentation studies infants relied on the presence of a pause, thus using a simpler strategy than the processing of prosodic boundaries.

The experiments reported in this chapter not only address the effect of phrasal prosody in early word segmentation beyond the edge factor, by examining prosodic boundaries in utterance internal position, but do so in the absence of pause cues. We wanted to investigate the ability of EP- learning 12 month-olds to segment monossyllabic word forms in utterance-internal position, but at the edge of an IP boundary. In other words, we aim to test the prosodic level at which the edge effect could be found, since utterance edges are also IP edges, unlike utterance internal IP boundaries which are only IP edges. In EP, the differences between utterance internal IP and utterance final IP boundaries are differences in the degree of the same types of cues, such as the degree of final lengthening, or of pitch range amplitude (Frota, 2014). Following previous results that suggested that by 9-month of age EP- learning infants have started to develop segmentation abilities in utterance internal position, we tested 12-month-olds use of phrasal prosody for segmentation utterance-internally, in two conditions: when target word forms were not followed by a phrasal boundary (the PW condition), and when they were followed by an IP boundary, without the pause cue. If 12-month-olds have fully developed their segmentation abilities, they should be able to demonstrate segmentation in either condition; if phrasal prosody constrains early word segmentation beyond the utterance edge, then infants are expected to perform better in the IP condition.

In two experiments, 1) the IP-boundary experiment and 2) the PW-boundary experiment, we investigated whether EP-learning 12 month-olds word segmentation abilities took into account the position of the target word form in the prosodic structure of the passages they were exposed to. Besides assessing the relevance of phrasal prosody for early word segmentation, the experiments that follow contribute to deepen our knowledge of (i) the role played by different boundary levels and boundary cues in word segmentation, and (ii) the developmental path of early word segmentation abilities as a function of prosody in a language like EP, that differently from English, French or Spanish displays a mixture of both stress and syllable-timing properties, and combines strong cues to high prosodic phrase boundaries and word boundaries, but not to lower phrase boundaries (Frota & Vigário 2001; Vigário, 2003; Frota 2014 – see also Chapter 2).

5.2 Experiment I: IP boundary in utterance-internal position

5.2.1 Method:

- *Participants*

Twenty 12-month-old infants from monolingual homes in the Lisbon area participated in this experiment (10 boys, mean age 12 month and 2 days, range 10 month and 24 days – 13 month and 19 days). Infants were tested at their nursery, after nursery directory board authorization and informative consent forms signed by parents. Two additional infants participated in the study, but were excluded due to fussiness. As in the previous studies, parents reported no known hearing deficits, cognitive or other neurological conditions based on regular medical evaluation.

- *Materials*

Four pseudo-words were used as targets - *Queu*, *Pis*, *Sau* and *Ful* , as in Butler, Severino, Vigário, & Frota (2016). All pseudo-words followed frequent phonotactic patterns found in the phonology of the language. The use of pseudo-words, and not real words, allowed us to control for any lexical biases caused by potentially known words. Six sentences were created for each word, and in each sentence the word was placed immediately before a utterance-internal Intonational Phrase boundary, as in the example '*Oferecemos-te **ful*** $]_{IP}$ *mas ficaste triste*' (We offered you **ful** but that made you unhappy).

To control for weight effects, syllable distribution before and after the IP boundary was balanced (5 to 6 syllables). According to findings in Elordieta et al. (2005), for production, and in Frota et al. (2010) and Severino (2011) for comprehension, Intonational Phrases require a minimal number of syllables to be perceived as such by European Portuguese adult speakers (at least 6 syllables), even in the presence of strong cues such as a pause. We opted for the natural production of the sentences without the pause cue, thus testing the impact of phrasal prosody on the basis of intonation and duration cues. The passages used are given in Appendix I.

Sentences were recorded by a female native speaker of EP at 22050hz, mono, 16 bit, at the Lisbon Baby Lab. The recordings were edited to build sentence passages of each word, with a total of 4 passages with 6 sentences each. Passages sound files had an average duration of 19,230ms (min. 18,81ms; max. 19,91ms), with an internal silence interval of 500ms between sentences, and an extra 100ms at the passage onset and offset. These passages were used in the familiarization phase. The same speaker recorded different productions of target words in isolation. For isolated words, we used the edited sound files from Butler, Severino, Vigário, & Frota (2016). They were edited to build a string of 15 repetitions of a target word, with an average duration of 18,790ms (min. 16,876ms; max. 20,024ms) in total, and with an internal silence interval of 500ms between words, and on the onset and offset of the edited files. These isolated-word passages were used in the test phase.

For the description of the prosodic boundary cues present in the stimuli, sentences were acoustically analyzed using PRAAT (Boersma & Weenink, 1992-2015). A four-tier text grid was created for the annotation of words, syllables, syllable duration, and prosodic boundary at target word, respectively (Figure 5.1).

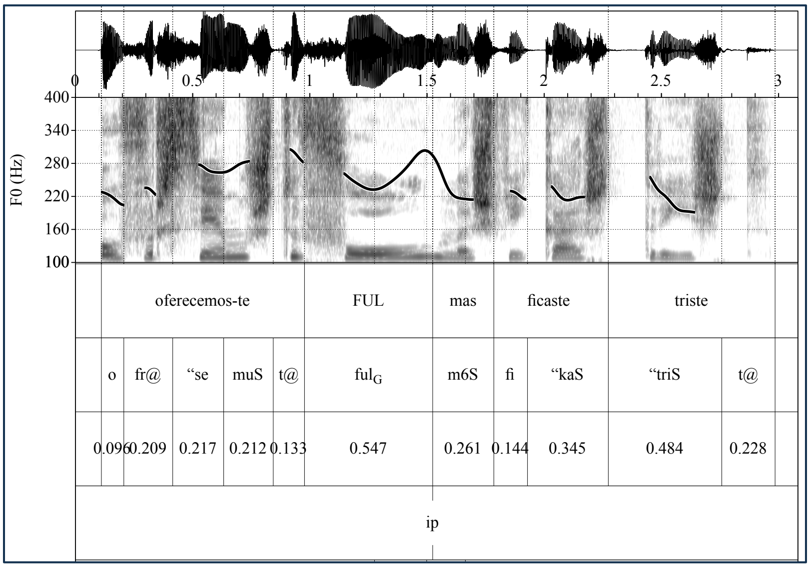

Figure 5.1: Annotations and acoustic analysis performed over IP-boundary sentences (example: ‘Oferecemos-te **ful** $]_{IP}$ mas ficaste triste’, We offered you **ful** but that made you unhappy).

Several acoustic measurements were performed: sentence length, syllable duration before and after boundary, pitch range[11], and pitch reset[12]. The presence and type of tonal event at the boundary was also annotated, following the P-ToBI system (Frota et al. 2015). The defining features of the sentences are given in Table 5.1.

[11] pitch range: *f*0 difference between the value of highest and lowest pitch point of the target monosyllable.
[12] pitch reset: *f*0 difference between the stable point of the vowel after target monosyllable and the.value of target monosyllable’s highest pitch point.

Table 5.1: Prosodic properties of IP boundary sentences.

IP boundary	sentence length (ms)	syllabic duration_before boundary (ms)	syllabic duration_after boundary (ms)	pitch range (hz)	pitch reset (hz)	tonal event
average	2,749	0,544	0,232	85,92	-93,45	H%
standard deviation	0,224	0,043	0,054	37,43	34,06	

- *Procedure*

A modified version of the visual habituation paradigm was used (Altvader-Mackensen & Mani, 2013). The apparatus needed included one monitor and loudspeakers for stimuli presentation, a laptop, camera, and video camera for experimenter control. Infants and experimenter were placed in different areas. Infants sat on the lap of their caregivers facing a monitor. The experimenter observed infants' behavior through the video camera and wore headphones and listened to music for stimuli sound masking during all of the experiment.

A familiarization phase and a test phase composed the experiment. The familiarization phase included 20 trials, each with a passage of one of two target words (e.g. 10 for *Queu* and 10 for *Ful*). In this phase, passages of two pseudo-words were presented alternately. Whenever the infant was looking at the monitor, a predefined keyboard button was pressed (looking to mid), while looking away resulted in button relief (looking to other). An attention getter was continuously shown between trials (a picture of a koala). When the infant was too distracted to look at the image, a *boing* sound was played to call attention. Trial presentation was set to start if the infant looked at the attention getter for more than 2000ms, and each trial ended when the passage sound ended or when the infant looked away from the screen for more than 2000ms (Zemach, Chang, & Teller, 2007; Taylor, Schloss, Palmer, & Franklin, 2013). Familiarization was considered to be reached when infants accumulated 45s of looking time for each of the two target word passages or went through all 20 trials. After this, the test phase started and infants listened to three blocks of the four isolated-word strings, with two familiar and two novel pseudo-words (Figure 5.2). Sound strings were randomized within blocks, so the same string was never played more than twice in a row. Test trials ended when infant looked away for more than 2000ms and the test phase ended when all blocks were presented.

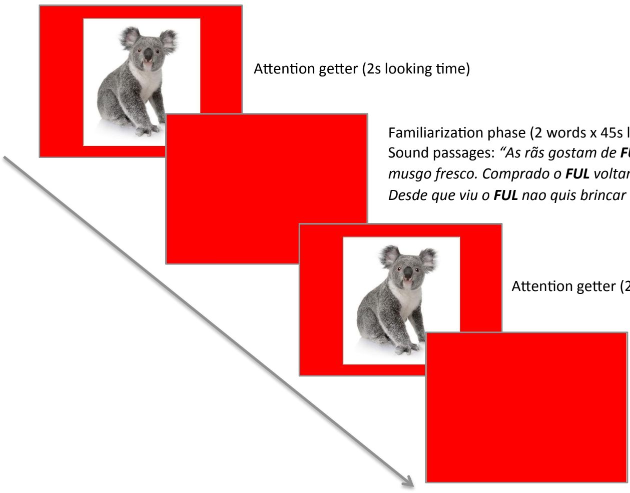

Figure 5.2: Events' sequence during experiment.

Four experimental conditions were created based on presentation onset in the familiarization phase: Ful-Pis and Pis-Ful, Queu-Sau , Sau-Queu.

Half of the infants were assigned to group 1 (the Ful/Pis group) and the other half to Group 2 (the Queu/Sau group). Infants were randomly assigned to each experimental condition and group.

5.2.2 Data processing

Experiment implementation and data collection were conducted using the Lincoln Infant Lab Package (Meints, K. & Woodford, A., 2008). Looking times to the monitor and looking times elsewhere were recorded for each subject throughout trials and automatically recorded for each subject by the software, and total looking times for each trial was calculated. For test trials, the total looking times to the three presented strings of each word were averaged. These values were then used as dependent variables. Segmentation was demonstrated by longer looking times to familiar word forms compared with novel words.

5.2.3 Data analysis

For data analysis, we conducted a 2x2 repeated measures ANOVA over the 20 subjects data, with total looking time to Stimuli Type (familiarized words vs novel words) as a within-subject factor and Word Group (group 1: ful/pis; group 2: sau/queu) as a between-subject factor.

5.2.4 Results

Results showed a significant effect of Stimuli Type ($F(1, 18) = 23{,}6$; $p = 0.000$; $\eta 2 = .567$), indicating that EP 12-month-old infants were able to segment words in sentence medial position, when the target word precedes a IP boundary not signaled with a pause. This shows that infants were sensitive to IP boundaries, despite the absence of a strong cue such as a pause. No word group effect was observed ($F(1, 18) = 2,606$; $p = 0.124$; $\eta 2 = .126$), and no interaction ($F(1, 18) = 2,837$; $p = 0.109$; $\eta 2 = .136$), with subjects behaving similarly independently of the words they were familiarized with. Average looking times in the test phase are presented in Figure 5.3. In the test phase, 17 out of 20 infants looked longer to the familiarized pseudo-words.

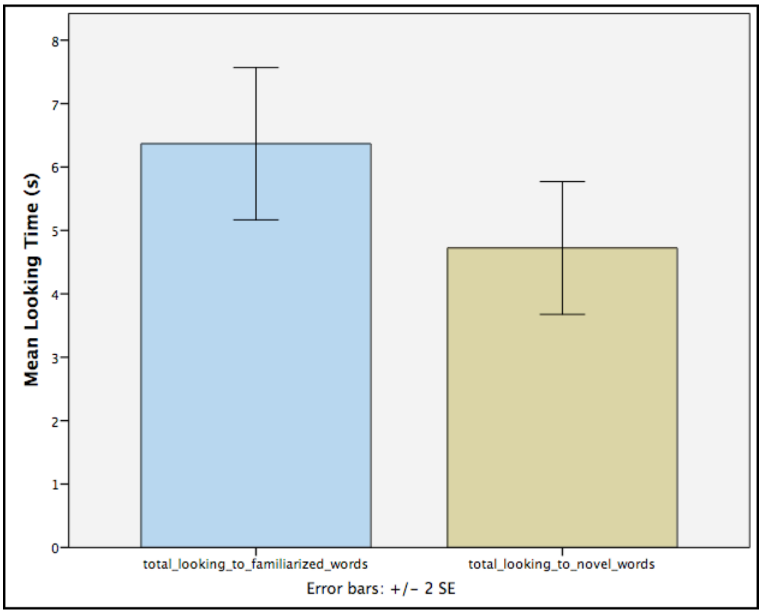

Figure 5.3: Mean looking time to familiarized and to novel words

5.2.5 Discussion

In a modified version of the visual habituation paradigm, EP-learning 12-month-olds were able to segment words in sentence medial position, when the target word preceded an IP boundary (despite the absence of a pause).

This finding provides clear support for the role of phrasal prosody in early word segmentation, showing that infants are sensitive to high level (IP) boundary properties to extract word forms from continuous speech. IP boundary effects in word segmentation at utterance middle position in the absence of a pause showed that pitch and durational cues were sufficiently salient in the acoustic signal for the processing of a prosodic boundary. In the light of previous studies, where word position at the utterance level (edge/mid) was the relevant condition, these results can be interpreted as showing the IP boundary is the relevant prosodic level affecting early segmentation even at the utterance edge.

In the following experiment, we tested early segmentation abilities at utterance middle position when the target word simply aligns with a PW boundary.

5.3 Experiment II: PW boundary in utterance-internal position

5.3.1 Method:

- *Participants*

Twenty 12-month-old infants from monolingual homes in the Lisbon area participated in this experiment (11 Boys, mean age 12 month 10 days, range 10 month and 15 days– 14 month and 22 days). Three other participants were excluded: two due to fussiness, and one due to experimenter error. Like in Experiment I, infants were tested individually at their nursery school in a quiet room. The school directory board and infants' parents filled written consent forms and only those infants with signed forms were tested. All nurseries were located in the Lisbon area. Parents reported no known hearing deficits, cognitive or other neurological conditions based on regular medical evaluation

- *Materials and procedure*

For this experiment, the materials and procedure were identical to experiment 1. In the materials, the crucial difference was in the position of target words within the prosodic structure of sentences. Target words were simply followed by a PW boundary, as in the example '*Aquele grande **ful***]$_{PW}$ *branco é da Quica*' (literally, That big white ful belongs to Quica). The same female speaker recorded the sentences used for the passages (all passages are given in Appendix I). The isolated word strings were the same as in Experiment 1.

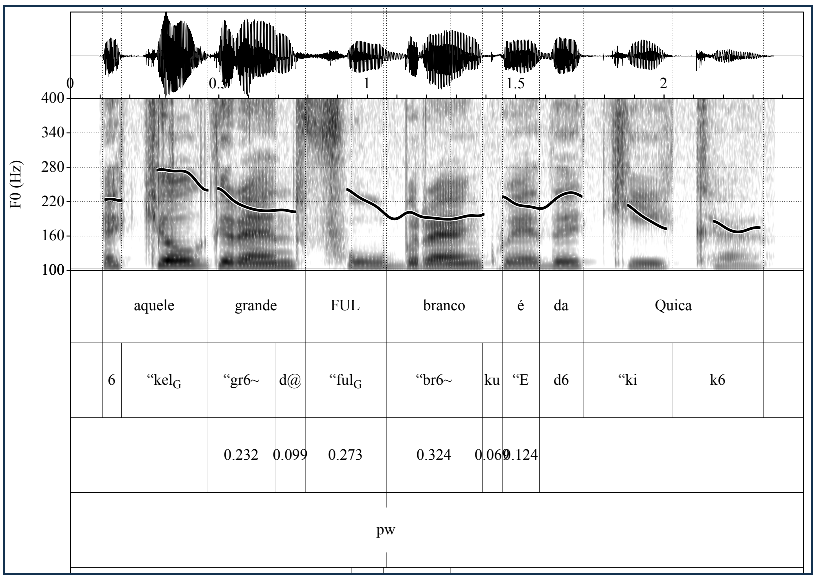

Figure 5.4: Annotations and acoustic analysis performed over PW boundary sentences. (example: *Aquele grande **ful**]*$_{PW}$ *branco é da Quica*', That big **ful** white belongs to Quica).

An example of a sentence is provided in Figure 5.4. Passage sound files had an average duration of 16,848ms (min. 16,538ms; max. 17,206ms). Results from the acoustic analysis of PW boundary sentences can be seen in Table 5.2.

Table 5.2: Prosodic properties of PW boundary sentences.

PW boundary	sentence length (ms)	syllabic duration_before boundary (ms)	syllabic duration_after boundary (ms)	pitch range (hz)	pitch reset (hz)	tonal event
average	2,338	0,289	0,260	-29,71	-31,33	--
standard deviation	0,224	0,033	0,056	14,09	21,56	

These results were compared with those presented in Table 5.1, for IP boundary sentences. Paired t-tests showed significant differences in syllable duration before boundary ($t(23) = 6.695$, $p = 0.000$, with longer durations at the IP sentences), significant pitch range differences ($t(23) = 15.787$, $p = 0.000$, with larger pitch range in IP sentences), and significant pitch reset differences ($t(23) = -6.492$, $p = 0.000$, with clear pitch reset found in IP sentences).

5.3.2 Data processing and analysis

Data processing and analysis were the same as in Experiment 1.

5.3.3 Results

A repeated measures ANOVA revealed no main effects of Stimuli Type (familiarized words vs novel words - $F(1,18) = 1,776$; $p = 0.199$; $\eta 2 = .090$), word group (group 1: ful/pis; group 2: sau/queu - $F(1, 18) = 0,000$; $p = 0.988$; $\eta 2 = .000$), and no interaction ($F(1,18) = 1,590$; $p = 0.223$; $\eta 2 = .081$). These results indicate that EP-learning 12-month-old were unable to segment target words in utterance internal position in the absence of IP boundary cues. Average looking times for familiarized and novel words are given in Figure 5.5. Only seven out of twenty infants looked longer to familiarized pseudo-words than to novel words (and 6 showed no difference in looking time between conditions).

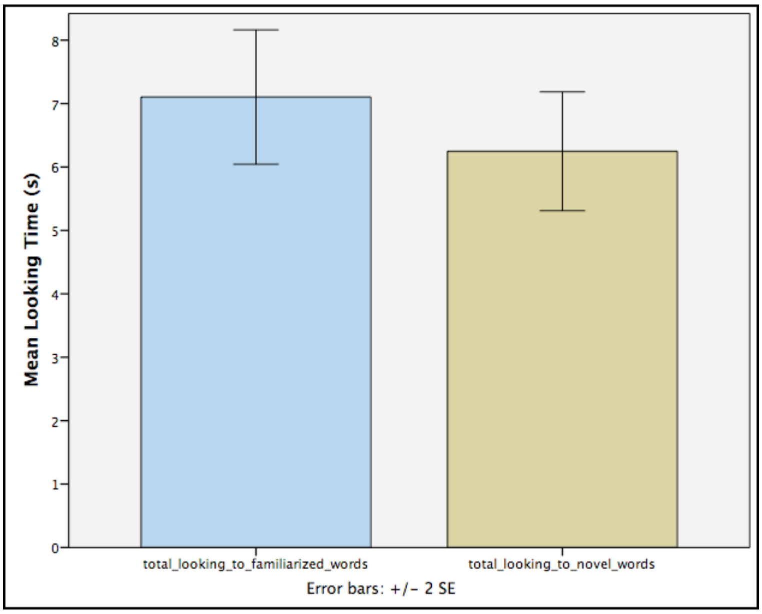

Figure 5.5: Mean looking time to familiarized and to novel words.

5.3.4 Discussion

Although EP-learning 12-month-olds were able to segment words in sentence medial position, when the target word preceded an IP boundary (and despite the absence of a pause), as shown in Experiment I, 12-month-olds were unable to demonstrate segmentation abilities at sentence medial position when the target word simply aligns with a PW boundary. The findings from Experiment II provide further evidence for the role of phrasal prosody in early word segmentation, showing that infants use high level (IP) boundaries to extract word forms from continuous speech in internal sentence position, but are unable to segment without the support of phrasal prosody. Furthermore, the results for individual looking preferences toward familiarized versus novel words, showed a mixed behavior (almost) evenly distributed among participants. A similar shift in preferences was reported in other segmentation studies and it has been associated to task difficulties (Hunter & Ames, 1988; Johnson, Seidl, & Tyler, 2014; DePaolis, Keren-Portnoy, & Vihman, 2016). This provides further indication that word segmentation in utterance internal position is still a difficult task for EP-learning 12-month-olds.

5.4 Final discussion

The two experiments reported in this chapter show that early segmentation abilities are strongly constrained by phrasal prosody. Indeed, by 12 months of age, EP-learning infants demonstrated an ability to segment word forms from continuous speech when the target word was aligned with an IP boundary, but not in the absence of a phrasal boundary. Therefore, segmentation abilities crucially depended on the location of the target word in the prosodic structure of the utterance. To our knowledge, the current study is the first to look at early word segmentation beyond the utterance edge versus utterance mid position, and to report that phrasal prosody constrains word segmentation beyond the utterance edge.

Only few studies in the word segmentation literature had previously addressed the role of phrasal prosody in early word segmentation abilities. In these studies, an advantage for segmentation at the edges of utterances was clearly shown, both for English and EP-learning infants, and around the same ages, namely between 6 and 9 months (Seidl & Johnson, 2006; Johnson et al., 2014; Butler, Severino, Vigário, & Frota, 2016). This earlier work provided cross-linguistic evidence for the so-called edge factor in early word segmentation. However, in these studies there was a pause among the prosodic cues for the edge condition, which raised the possibility that infants were relying on the presence of a pause and thus using a simpler strategy than the processing of phrasal prosody. By examining the role played by difference boundary levels and boundary cues in utterance internal position, and in the absence of the pause cue, we are able to clarify and strengthen previous claims about infants' use of prosody in early word segmentation (Fernald & Mazzie, 1991; Floccia et al 2016). Specifically, the current findings have shown that IP boundary cues were successfully used for word segmentation, namely the pitch and durational changes that characterized IP boundaries in EP, even if such boundaries did not coincide with utterance edges; by contrast, in the absence of such cues, as in the case of word edges within a prosodic phrase, infants fail to extract words from continuous speech.

The ability to track and retrieve words from the context of continuous speech is fundamental to language development, as a prerequisite to word learning and lexical development, as well as to the acquisition of syntax (Newman et al., 2006; Singh et al., 2012). A few studies have suggested correlations been early word segmentation abilities (or the lack of such abilities) and later language outcomes, across (Millotte, Morgan, Margules, Bernal, Dutat, & Christophe, 2010; Floccia et al. 2016) and within languages (Newman et al., 2006; Singh et al., 2012). Infants' demonstrated ability to use phrasal prosody in word segmentation, beyond the utterance edge factor, guides them to locate and extract words from continuous speech. As phrasal prosody is found in all languages, a relevant question is whether differences in word segmentation abilities across and within languages could be related to infants' abilities to use phrasal prosody for segmentation. It is known that the prosodic features of infant-directed speech show important cross-linguistic differences (Fernald et al. 1989; DePaolis, Keren-Portnoy & Vihman, 2010). Crucially, and beyond IDS, the prosody of languages and language varieties also differs in crucial ways (Jun 2005, 2014; Frota & Prieto 2015), showing distinct prosodic phrasing levels (for example, French has three different levels of intonationally marked prosodic phrases, English has two and European Portuguese only one) and/or distinct implementations of the same kinds of prosody boundaries (as in the case of phonological phrases boundaries which are very salient in French, but not in European Portuguese).

To start to tackle the issue of whether differences in word segmentation abilities across and within languages could be related to infants' abilities to use phrasal prosody for segmentation, studies on languages that differ in their prosody need to be conducted. The current study also contributes to this line of research, since the language under study, EP, displays atypical prosodic properties: EP, differently from English, French or Spanish, displays a mixture of both stress and syllable-timing properties, and unlike French or Spanish, combines strong cues to high prosodic phrase boundaries and word boundaries, but not to lower phrase boundaries (Frota & Vigário 2001; Vigário, 2003; Frota 2014 – see also Chapter 2). Our current knowledge of the developmental path of early word segmentation abilities in EP shows a similar early utterance edge effect as in English, with utterance internal segmentation constrained by phrasal prosody, namely the presence of an IP boundary. The two experiments reported in this chapter showed that 12-month-olds have not yet fully developed their segmentation abilities, given that infants' performance was only successful with the support of phrasal prosody, and they failed to use word level prosody. It seems thus relevant to investigate word segmentation in the PW boundary condition at later ages.

Further research, on EP and other languages, is therefore needed to deepen our knowledge of how phrasal prosody impacts on the development of early word segmentation abilities.

6 Conclusion

The studies presented in this work focused on the role of phrasal prosody in the segmentation of speech into linguistics units and structures in three experimental conditions: 1) globally ambiguous sentences involving a low or high attachment interpretation of a given constituent, and where phrasal prosody has an optional nature and is usually intentionally produced by the speaker for disambiguating reasons (chapter 3); 2) globally ambiguous sentences where the phrasal prosody is part of the default prosody triggered by the syntax-prosody interface, and is thus directly linked to a given syntactic structure and sentence interpretation (chapter 4); and 3) the use of phrasal prosody to chunk the speech signal into words by infants, in the absence of prior lexical knowledge (chapter 5).

Considering first the adult system that is targeted by infants acquiring EP, the results provided by the experiments here reported revealed that adults were unable to use phrasal prosody to disambiguate sentence structures in a condition where phrasal prosody is not directly triggered by the syntax-prosody mapping, as in 1). By contrast, when the default prosody of the sentence is guided by this same syntax-prosody mapping, as in 2), clear evidence was found for the impact of prosody in the resolution of the ambiguous sentence, with sentence interpretation being guided by prosodic cues. These results have set the stage for examining the role of phrasal prosody in ambiguity resolution from the perspective of language development. If young children have the ability to interpret phrasal prosody as cuing syntactic structure, we expected that differences in phrasal prosody were used to guide sentence interpretation. In other words, phrasal prosody, which is readily available in the signal, might inform lexical and syntactic processing, along the lines of the prosodic bootstrapping hypothesis (Morgan & Demuth, 1996; Höhle, 2009).

Our findings showed the ability of EP children to resolve global ambiguity on the basis of prosodic information from age 5, revealing a clear developmental path in the use of phrasal prosody to guide sentence interpretation: from a general inability at age 4 to a still developing ability at age 5, when local prosodic cues were still not enough (unlike for adults) and the support of distal prosodic cues was necessary to achieve disambiguation. The fact that EP-learning children seem to develop this ability only at age 5, finds support in some previous work on other languages (e.g., Choi & Mazuka, 2003; Snedeker & Yuang, 2008), and seems at odds with other reports that children of 4 years of age or even younger use phrasal prosody to interpret syntactic ambiguous sentences (De Carvalho et al., 2016a for French). The comparison with findings from previous work on other languages suggests that differences in the types of cues present in the sentences together with language-specific use/weight of prosodic cues as possible sources of explanation for similar (e.g., Choi & Mazuka, 2003, for Korean; Snedeker & Yuang, 2008, for English) and different findings (De Carvalho et al., 2016a). For example, French prosody is phrased-based with accentual phrases being marked with pitch movements and duration cues at their edges (Jun & Fougeron, 2002; Jun, 2014), whereas EP is a language where only the head of the IP is systematically marked with pitch and duration cues (Frota 2000, 2014). The presence of regular and frequent prosodic cues in French versus irregular and sparse cues in EP makes French children more exposed, and possible more sensitive, to (at least certain types of) prosodic cues, and thus better able to exploit them for sentence parsing earlier in development.

While the previous experiments investigated the ability to use prosody to constrain lexical and syntactic analysis, thus looking into the combination of lexical, syntactic and prosodic knowledge at a young age, the sensitivity that infants show to prosody from birth and in the first months of life (Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, Druss et al., 1987; Nazzi, Bertoncini & Mehler, 1998; Nazzi, Floccia & Bertoncini, 1998; Frota, Butler & Vigário, 2014, among many others) is highly suggestive of its potential bootstrapping role much earlier in development, in the absence of other prior linguistic knowledge, such as lexical knowledge. The ability to track and retrieve words from the context of continuous speech is fundamental to language development, as a prerequisite to word learning and lexical development, as well as to the acquisition of syntax (Newman et al., 2006; Singh et al., 2012). In the set of experiments in 3) we asked whether phrasal prosody was exploited to chunk the speech signal into words by infants, in the absence of prior lexical knowledge. Our findings showed that early segmentation abilities are constrained by phrasal prosody, since they crucially depend on the location of the target word in the prosodic structure of the utterance. Earlier work had provided cross-linguistic evidence for the so-called edge factor in early word segmentation, i.e., infants showed an advantage for segmentation at the edges of utterances (Seidl & Johnson, 2006; Johnson et al., 2014; Butler, Severino, Vigário, & Frota, 2016). The studies in this thesis examined the role played by different boundary levels and boundary cues in utterance internal position (IP and PW), and in the absence of a pause cue, thus clarifying and strengthening previous claims about infants' use of prosody in early word segmentation (Fernald & Mazzie, 1991; Floccia et al 2016). Infants' demonstrated ability to use phrasal prosody in word segmentation, beyond the utterance edge factor, guides them to locate and extract words from continuous speech. As phrasal prosody is found in all languages, a relevant question, yet to be answered, is whether differences in word segmentation abilities across and within languages (Newman et al., 2006; Millotte, Margules, Dutat, Bernal & Christophe, 2010; Floccia et al. 2016) could be related to infants' abilities to use phrasal prosody for segmentation.

Again, this question leads us to acknowledge and study the potential impact of prosodic differences within and across languages, and on infants' and young children's abilities to exploit phrasal prosody in language acquisition. Although phrasal prosody is found in all languages, the prosodic features of infant-directed speech are known to differ across languages (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, & Fukui, 1989; DePaolis, Keren-Portnoy & Vihman, 2010), and the language-specific prosodic systems are also known to vary in many crucial respects (Jun S., 2005, 2014; Frota & Prieto, 2015). By studying EP, a language with atypical prosodic properties (different from English, Spanish, or French), we hope to have made a contribution to our understanding of the role of phrasal prosody in language development. Further studies in this domain, in EP and other (less studied) languages and varieties, are needed in future research.

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Appendix I

EXPERIMENTAL MATERIALS

The sound files of the corpora for the four experiments are available at the following website:
http://labfon.letras.ulisboa.pt/babylab/teses/CatiaSeverino/materiais.html

Chapter 4: Young children's use of phrasal prosody in globally ambiguous sentences

Test items

1a O Tito já disse guarda-chuva e pato.	*Tito already said umbrella and duck.*
1b O Tito já disse guarda, chuva e pato.	*Tito already said guard, rain and duck.*
2a O Tito logo gritou porta-chaves e bola.	*Tito promptly yelled keychain and ball.*
2b O Tito logo gritou porta, chaves e bola.	*Tito promptly yelled door, keys and ball.*
3a O Tito só ouviu porco-espinho e carro.	*Tito only heard porcupine and car.*
3b O Tito só ouviu porco, espinho e carro.	*Tito only heard pig, thorn and car.*
4a O Tito apenas viu saco-cama e maçã.	*Tito only saw (the) sleeping bag and (the) apple.*
4b O Tito apenas viu saco, cama e maçã.	*Tito only saw (the) bag, (the) bed and (the) apple.*
5a O Tito já comprou fita-cola e papel.	*Tito already bought duct tape and paper.*
5b O Tito já comprou fita, cola e papel.	*Tito already bought tape, glue and paper.*
6a O Tito também leu peixe-espada e mesa.	*Tito also read swordfish and table.*
6b O Tito também leu peixe, espada e mesa.	*Tito also read fish, sword and table.*
7a O Tito só escolheu bolo-rei e lapis.	*Tito only chose king cake and pencil.*
7b O Tito só escolheu bolo, rei e lápis.	*Tito only chose cake, king and pencil.*

Non-targets

O Tito tirou sapatos azuis e colher.	*Tito took blue shoes and (a) spoon.*
O Tito levou banana e maçã.	*Tito took (a) banana and (an) apple.*
O Tito deu livros e pão.	*Tito gave books and bread.*
O Tito comprou casacos e flores.	*Tito bought mugs coat and flowers.*
O Tito viu meias e chapéus.	*Tito saw socks and hats.*
O Tito brincou com bolas e puzzles.	*Tito played with balls and puzzles.*
O Tito também comeu sopa e morangos.	*Tito also ate soup and strawberries.*
O Tito gosta de árvores e gatos.	*Tito likes trees and cats.*
O Tito gosta de bolacha e avião.	*Tito likes cookies and planes.*
O Tito viu estrela e casa.	*Tito saw (a) star and (a) house.*
O Tito escolheu colher e tartaruga.	*Tito chose (a) spoon and (a) turtle.*

Chapter 5: Beyond the edge factor: Phrasal prosody constrains word segmentation by 12-month-olds

Experiment 1: IP boundary in utterance-internal position

Passage 1

As rãs gostam de FUL]$_{IP}$ em vez de musgo fresco.

Comprado o FUL]$_{IP}$ voltamos ao parque.

Desde que viu o FUL]$_{IP}$ não quis brincar mais.

Oferecemos-te FUL]$_{IP}$ mas ficaste triste.

Experiment 2: PW boundary in utterance-internal position

Passage 1

A caixa contém [FUL $_{PW}$ vermelho]$_{PhP}$ na tampa.

Aquele grande [FUL $_{PW}$ branco]$_{PhP}$ é da Quica.

Comeram muito [FUL $_{PW}$ doce]$_{PhP}$ na praia.

Hoje vi um [FUL $_{PW}$ castanho]$_{PhP}$ mas duro.

Quanto à luz FUL]$_{IP}$ nunca foi testada.

Vocês prendem o FUL]$_{IP}$ porém ele fugiu.

Passage 2

Adoro beber PIS]$_{IP}$ nunca com água.

Arranjado o PIS]$_{IP}$ dançámos juntos.

Depois deste PIS]$_{IP}$ prefiro as bolas.

O Tó molhou o PIS]$_{IP}$ mas sem o estragar.

Pretendo dar um PIS]$_{IP}$ se me deres uma flor.

Se nos vestirmos PIS]$_{IP}$ ficamos quentinhos.

Passage 3

As rãs gostam de QUEU]$_{IP}$ em vez de musgo fresco.

Comprado o QUEU]$_{IP}$ voltamos ao parque.

Desde que viu o QUEU]$_{IP}$ não quis brincar mais.

Oferecemos-te QUEU]$_{IP}$ mas ficaste triste.

Quanto à luz QUEU]$_{IP}$ nunca foi testada.

Vocês prendem o QUEU]$_{IP}$ porém ele fugiu.

Passage 4

Adoro beber SAU]$_{IP}$ nunca com água.

Arranjado o SAU]$_{IP}$ dançámos juntos.

Depois deste SAU]$_{IP}$ prefiro as bolas.

O Tó molhou o SAU]$_{IP}$ mas sem o estragar.

Pretendo dar um SAU]$_{IP}$ se me deres uma flor.

Se nos vestirmos SAU]$_{IP}$ ficamos quentinhos.

O amigo do [FUL $_{PW}$ português]$_{PhP}$ fugiu.

O outro [FUL $_{PW}$ branco]$_{PhP}$ foi de mercedes.

Passage 2

Agora este [PIS $_{PW}$ voador]$_{PhP}$ já saiu.

Eles trouxeram [PIS $_{PW}$ quente]$_{PhP}$ para casa.

Estes primos do [PIS $_{PW}$ francês]$_{PhP}$ apenas dançam .

Na prova fiz [PIS $_{PW}$ vegetariano]$_{PhP}$.

Ontem havia [PIS $_{PW}$ grego]$_{PhP}$ para dar.

Todo aquele [PIS $_{PW}$ seco]$_{PhP}$ foi regado.

Passage 3

A caixa contém [QUEU $_{PW}$ vermelho]$_{PhP}$ na tampa.

Aquele grande [QUEU $_{PW}$ branco]$_{PhP}$ é da Quica.

Comeram muito [QUEU $_{PW}$ doce]$_{PhP}$ na praia.

Hoje vi um [QUEU $_{PW}$ castanho]$_{PhP}$ mas duro.

O amigo do [QUEU $_{PW}$ português]$_{PhP}$ fugiu.

O outro [QUEU $_{PW}$ branco]$_{PhP}$ foi de mercedes.

Passage 4

Agora este [SAU $_{PW}$ voador]$_{PhP}$ já saiu.

Eles trouxeram [SAU $_{PW}$ quente]$_{PhP}$ para casa.

Estes primos do [SAU $_{PW}$ francês]$_{PhP}$ apenas dançam .

Na prova fiz [SAU $_{PW}$ vegetariano]$_{PhP}$.

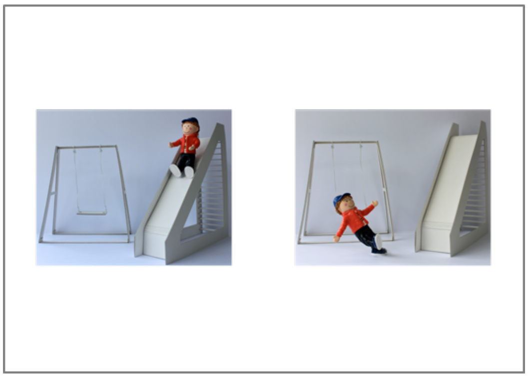
Ontem havia [SAU $_{PW}$ grego]$_{PhP}$ para dar.

Todo aquele [SAU $_{PW}$ seco]$_{PhP}$ foi regado.

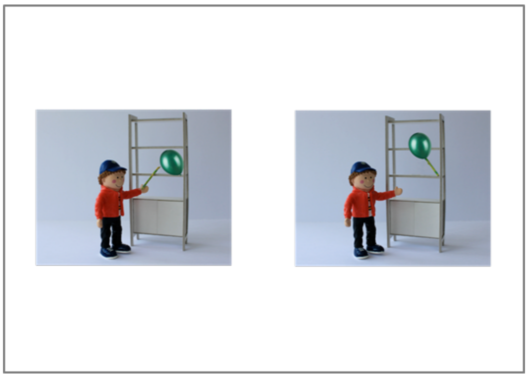
Appendix II

EXPERIMENTAL IMAGES

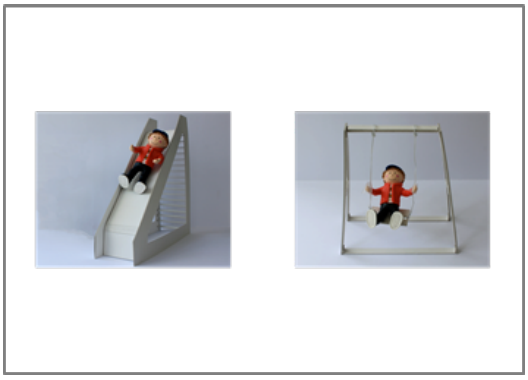
Chapter 3: Exploratory-pilot study: Phrasal prosody and syntactic ambiguity (Adults)



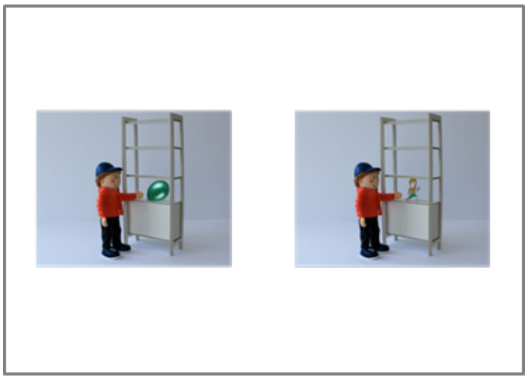
Left: O Tito anda$_{php}$ de baloiço$_{php}$ e escorrega
O Tito anda$_{ip}$ de baloiço$_{php}$ e escorrega.
Right: O Tito anda de baloiço$_{ip}$ e escorrega.



Left: O Tito tira$_{php}$ o balão$_{php}$ com o pau.
O Tito tira$_{ip}$ o balão$_{php}$ com o pau.
Right: O Tito tira$_{php}$ o balão$_{php}$ com o pau.



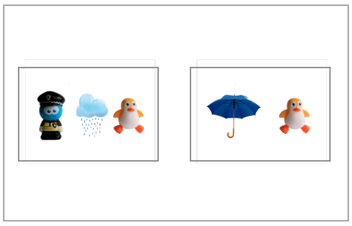
Right: O Tito anda de baloiço no recreio.



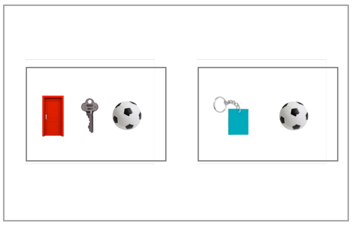
Left: O Tito tira o balão verde.

Chapter 4: Young children's use of phrasal prosody in globally ambiguous sentences

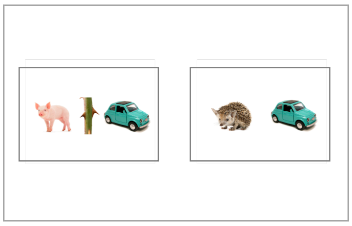
- Test items



Left: guarda, chuva e pato
Right: guarda-chuva e pato



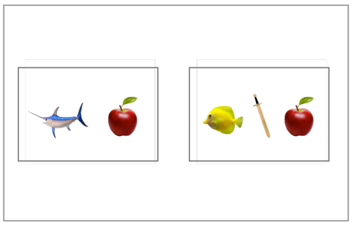
Left: porta, chave e bola
Right: porta-chave e bola



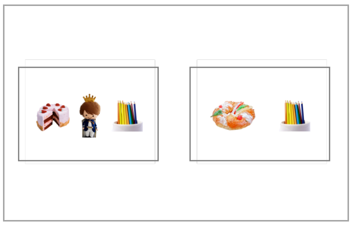
Left: porco, espinho e carro
Right: porco-espinho e carro

Left: saco-cama e mesa
Right: saco, cama e mesa

Left: fita, cola e papel
Right: fita-cola e papel



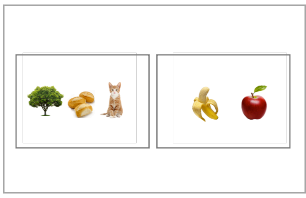
Left: peixe-espada e maçã
Right: peixe, espada e maçã



Left: bolo, rei e lápis
Right: bolo-rei e lápis

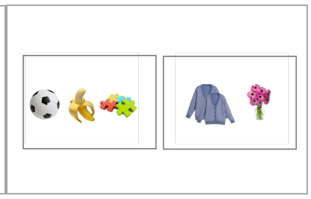
- Non-targets

Left: sapatos azuis e meias brancas



Right: banana e maçã

Left: livros e pão

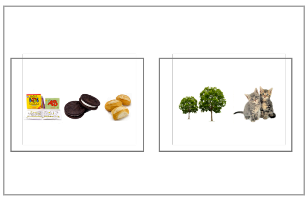


Right: casacos e flores

Left: meias e chapéu.

Right: bolas e puzzles.

Left: sopa e morangos



Right: árvores e gatos

Left: bolachas e aviões

Right: estrela e casa

Appendix III

CONSENT FORM

Car@ encarregad@ de educação,

O Lisbon BabyLab é um núcleo de investigação para o estudo da aquisição e desenvolvimento da linguagem, situado na Faculdade de Letras da Universidade de Lisboa e integrado no Centro de Linguística (http://www.fl.ul.pt/laboratoriofonetica/babylab/). Vimos convidar-vos a participar no nosso próximo estudo e desde já muito agradecemos a vossa colaboração no trabalho de investigação do BabyLab.

Para o estudo que estamos a desenvolver neste momento, a idade das crianças situa-se entre os 5 e os 13 meses. Neste estudo, observaremos como reage a criança a sequências de sons. Usando um método chamado Fixação do Olhar, observamos se a criança olha para um monitor com imagens quando ouve os sons. A tarefa é não invasiva e salienta-se que o contacto e acompanhamento das crianças será sempre feito por uma educadora do Jardim de Infância, limitando-se a investigadora a apenas fazer o registo automatizado da direcção do olhar com equipamento apropriado do Lisbon BabyLab. A tarefa demorará apenas cerca de 3 minutos.

Assim, queríamos perguntar-vos se autorizam a participação d@ voss@ educand@ neste estudo. Os materiais recolhidos destinam-se exclusivamente ao estudo em curso, não sendo **nunca** autorizada ou permitida a cedência/apresentação dos mesmos a terceiros. Estes serão **unicamente** acedidos pelos investigadores envolvidos e pelos encarregados de educação da criança. Em nenhum momento a criança estará sozinha, estando sempre acompanhada por uma educadora do infantário.

Em caso de dúvida, não hesitem em contactar-nos através do email labfon@fl.ul.pt ou pelo telefone [redacted] (Cátia Severino). A equipa de investigadores do Lisbon BabyLab tudo fará para vos prestar quaisquer esclarecimentos adicionais necessários.

Caso aceitem colaborar, por favor preencham e assinem a autorização abaixo.

Muito obrigada pela vossa colaboração!

Sónia Frota
(Directora do Laboratório de Fonética & Lisbon BabyLab, CLUL)

Eu, ____, abaixo assinado/a, autorizo o/a meu/minha educando/a __________________________________ a participar no estudo do Lisbon BabyLab sobre aquisição e desenvolvimento da linguagem, que terá lugar no/a ____.

O encarregado de educação,

____

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